QUANTITATIVE EVALUATION OF THE MOTION OF FROZEN SHOULDERS TREATED WITH ACUPUNCTURE BY PUNCTURING FROM TIAOKOU (ST. 38) TOWARDS CHENGSHAN (U.B. 57)

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ABSTRACT

Frozen shoulder is one of the most commonly reported shoulder disorders in adults between 40 and 60 years of age with significant pain and loss of joint range of motion (ROM), resulting in huge impact on the activities of daily living. Treatment of frozen shoulders with drugs, physical therapy and surgery that dealt with adhesive tissues may come with complications. Therefore, acupuncture therapy has become an important alternative. Puncturing needles from Tiaokou (St. 38) towards Chengshan (U.B. 57) has been used as a treatment specifically for frozen shoulders. To this day, no study on the quantitative evaluation of the efficacy of the treatment has been found in the literature. A quantitative and objective method using video-based stereophotogrammery system was developed to evaluate the treatment efficacy of acupuncture by inserting needle from St. 38 to U.B. 57. It was found that the treatment increased significantly the humeral elevation ROM from 102.91 ° ± 24.82 ° before treatment to 111.25 ° ± 22 ° after, with a mean increase of 8.34 ° . This finding confirms the teachings described in the classical Chinese medical literature and will be helpful for the planning and implementation of long-term studies on the treatment mechanism and efficacy of acupuncture in frozen shoulder.

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1. INTRODUCTION

The shoulder joint is one of the most mobile joints in the body, playing an important role in the normal function of the upper extremity. Any injury or disease of the shoulder will cause degradation or even loss of function of the upper limb with huge impact on activities of daily living. One of the most commonly reported shoulder disorders is frozen shoulder. Duplay [1] first noted the sign and symptoms of frozen shoulder in 1872. Because of unclear pathology and etiology of the disease, Codman [2] stated that frozen shoulder was difficult to define, to treat and to explain. To this day, clinical diagnosis of frozen shoulder is generally based on patient's subjective history and clinicianϒƒs objective findings. There has been a consensus that shoulder capsular adhesion is the fundamental etiology of this disease since the study of

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Neviaser [3]. However, with recent technological developments, arthroscopy and other imaging techniques have been used to identify the involved tissues, and several studies have shown that adhesive capsulitis [4], decreasing capsule volume [3, 5-7], losing dependent fold [4, 8], and contracture of the corahumeral ligament [9-10], capsule and fibrosis around the shoulder joint [11] all may possibly contribute to the development of frozen shoulder.

The progression of frozen shoulder has been divided into three phases with the spontaneous onset of pain in the shoulder with restricted movement as the starting point [12]. Phase Ⅰ(Pain Phase) is identified by pain and decreasing capsular volume; phase Ⅱ (Stiffness Phase) by stiffness and discomfort; and phase Ⅲ(Recovery Phase) by gradual recovery [12]. The total period of full recovery may take up to 6 years [8, 13].

Generally, treatment of frozen shoulder in the early stage included local rest with the arm in a sling, local heat and analgesics. Patients can also improve significantly by NSAIDs or by the systemic administration of adrenocorticosteroids. Inflation of the glenohumeral joint with injected saline is sometimes used in separating the adherent capsule from the humeral head. In the later stages if motion is not returning at a reasonable rate, surgical manipulation, or even operative treatment such as arthroscopic surgery, is occasionally required to release the contracture of the subscapularis muscle and to separate the adherent capsule from the articular cartilage of the humeral head [14]. Several studies have pointed out that treatment with drugs, either taking orally or local injection, with physical therapy, and with surgery that dealt with adhesive tissues may come with other complications. Therefore, treating patients with acupuncture therapy has become an important alternative.

In traditional Chinese medicine, acupuncture has been widely used in China since 2500 BC [15]. It is the practice of inserting needles into the skin and deeper tissues along 'meridians' to balance flow of bodily 'energy' or 'Xi'. Puncturing needles from Tiaokou (St. 38) towards Chengshan (U.B. 57) has been used as a treatment specifically for frozen shoulders. The point St. 38 is located 5 cun distal to St. 36 (Zusanli), which is 3 cun below the knee joint line, approximately 1 finger width lateral to the anterior boarder of the tibia (Fig. 1). The U.B. 57 is located inferior to the belly of the gastrocnemius muscle, midway between Weizhong (U.B. 40) and upper border of the calcaneum (Fig. 2). The needle is inserted into St. 38 through the muscle to U.B. 57. Pothman et al. [16] have reported a clinical study on the acupuncture therapy on patients with frozen shoulders with point St. 38. They found that St. 38 is one of the most important distal points in treating shoulder diseases and suggested that it should be used before attempting any treatment. To this day, no study on the quantitative evaluation of the efficacy of puncturing the needle from St. 38 to U.B. 57 for the treatment of frozen shoulder has been found in the literature.

The majority of previous studies investigated the range of humeral angle relative to the trunk using goniometers [17-18] or invasive bone pins [19-20]. It is noted that the motion of the shoulder complex is three-dimensional in nature. Measurements using

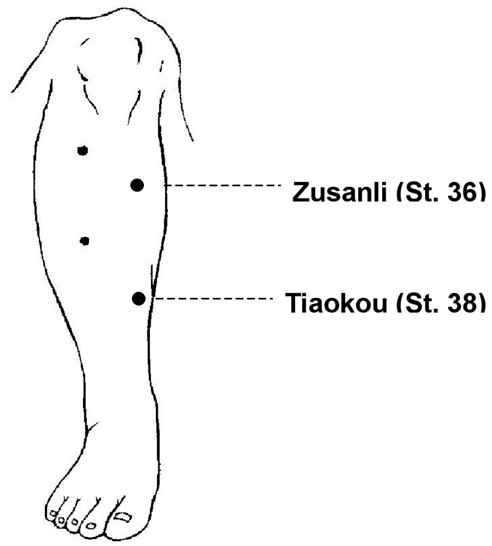

Fig 1. Position of the Tiaokuo (St. 38) point.

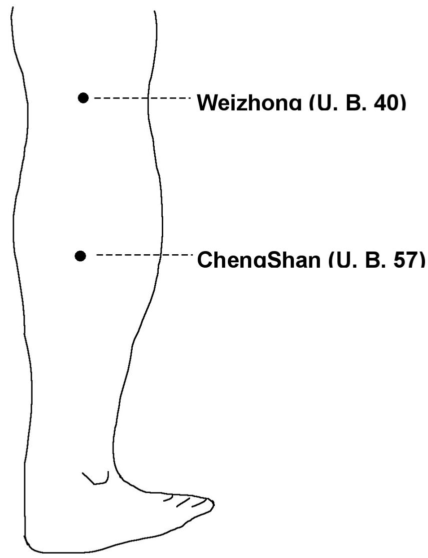

Fig 2. Position of the Chengshan (U.B. 57) point.

goniometers were limited to measuring planar components of the shoulder motion. Although bone pins could be used to measure the true motion of the joint, it is invasive and may increase chances of infection. The purpose of the present study was to evaluate quantitatively the motion of frozen shoulders by using video-based stereophotogrammetry before and after treatment with acupuncture by inserting the needle from Tiaokou (St. 38) to Chengshan (U.B. 57). It is hoped that the efficacy of this treatment can be scientifically evaluated and the developed measurement and evaluation technique will be helpful for the diagnosis of patients with frozen shoulders and for the subsequence planning and assessment of treatment.

2. METHODS

Fourteen subjects (8 males, 7 females, mean age: 56 years; mean height: 164 cm; mean weight: 66 kg) participated in the present study. All the subjects diagnosed of frozen shoulder (adhesive capsulitis of the shoulder joint) were recruited from Orthopaedics Departments of National Taiwan University Hospital and China Medical University Hospital. Ethics approval was authorised by the Committee of the China Medical University Hospital (DMRR93-IRB-01). Subjects all met the following inclusion criteria: (a) shoulder pain and rigidity for at least a month, (b) limitation in active and passive range of motion of the shoulder joint for at least 10 degrees, (c) the range of motion in pronation and supination were less than 45 degrees while those in abduction were less than 100 degrees, (d) free from other neuromusculoskeletal dysfunction and did not receive neck, thoracic and shoulder operation. The experimental procedure and purpose were explained to all the subjects and informed consents were obtained before tests. In a gait laboratory, eight infrared retroreflective markers were attached to the bony landmarks of the trunk and the affected upper arm of the subject to track the motion of the upper arm relative to the trunk. Four markers on the trunk were sternal notch (SN), xphoid process (XP), the 7th cervical spinal process (C7) and the 8th thoracic spinal process (T8). Four markers were placed on the lateral side of the upper arm and the positions of the medial and lateral epicondyles of the humerus (LEP, MEP) and the centre of the humeral head (GH) were indicated by a pointer during a subject calibration trial. Three-dimensional coordinates of these markers during tests were measured with a 7-camera motion analysis system (Vicon512, Oxford Metrics, U.K.).

Three test conditions were included in the study: control, sham and true treatment. The control condition was tested first before the subject received any treatment. Sham test condition was used to test possible psychological effects of the acupuncture treatment. It was performed by inserting 2-cun long needles into two non-acupoints, the first point (point a) being located at 5 cun above and 1 cun medial to the heel and the second (point b) at 2 cun above and 1 cun posterior to the medial malleolus, Fig. 3. Both the needles were then connected to an electric needling apparatus (Trio 300, I.T.O., Japan), with point a as positive pole and point b as negative. Electricity was then generated as an output of constant current of 0.5 mA, 1ms square pulse, at a maximal tolerable intensity (a strong, but not painful sensation as reported by the patient), and at 2Hz and lasted for 20 minutes. Following the sham test condition, true treatment was performed using a 2 cun long needle inserting it slowly from St. 38 (Fig. 1) to U.B. 57 (Fig 2). The puncture of St. 38 was performed perpendicularly for 1.5-2.5 cun with a sensation of soreness and distension in the front of the leg, radiating down to the dorsum of foot, and then the puncture was continued to the position of U.B. 57. The needle was also connected to the output of the electric needling apparatus with the same stimulating condition as in the sham test and lasted for 20 minutes. For all conditions, subjects were instructed to elevate their arms in the scapular plane (about 30 degrees anterior to the frontal plane) as much as possible until they felt pain. They then hold the arm at that position for 5 seconds while the kinematic data were recorded. Three trials for each condition were performed.

The use of video-based stereophotogrammertry in human movement analysis required determination of the poses (positions and orientations) of the body segments from skin markers. All the body segments were assumed as rigid bodies and at least three markers per segment were needed for the definition of the body-embedded local coordinate systems. Because of skin movement, the marker array on the body segment displaced and rotated relative to the underlying bone during motion, resulting in skin movement artefacts. In order to minimise these errors, segmental optimisation method (SOM) was used. It estimated the segment pose in terms of its transformation matrix by minimising marker array deformation from its reference shape in a least squares sense [21-24]. The transformation was obtained by solving the following optimisation problem:

$$\min \quad f = \sum_{i=1}^{m} (Rx_i + v - y_i)^T (Rx_i + v - y_i) \tag{1}$$

$$\text{s.t.} \quad R^T R = I \tag{2}$$

where x_i and y_i are position vectors of marker i in the marker array at the reference and current positions, respectively. R is the rotation matrix; v is the translation vector; and m is the number of markers. The constraint (2) ensures that the transformation is orthogonal, corresponding to rigid body motion. The minimum value of f is the segmental residual error, a measurement of the marker array deformation that is mainly due to skin movement artefacts.

In the present study, according to the suggestions from the International Society of Biomechanics (ISB), the local coordinate system of the trunk was defined by SN, XP, C7 and T8 with the origin at the mid point between XP and T8 as follows, Fig. 4 (a).

$$\bar{Y}_T = \frac{\frac{\bar{P}_{SN}+\bar{P}_{C7}}{2} - \frac{\bar{P}_{XP}+\bar{P}_{T8}}{2}}{\left|\frac{\bar{P}_{SN}+\bar{P}_{C7}}{2} - \frac{\bar{P}_{XP}+\bar{P}_{T8}}{2}\right|} \quad (3)$$

$$\bar{X}_T = \frac{(\frac{\bar{P}_{SN}+\bar{P}_{C7}}{2} - \bar{P}_{XP})\times(\frac{\bar{P}_{XP}+\bar{P}_{T8}}{2} - \bar{P}_{XP})}{\left|(\frac{\bar{P}_{SN}+\bar{P}_{C7}}{2} - \bar{P}_{XP})\times(\frac{\bar{P}_{XP}+\bar{P}_{T8}}{2} - \bar{P}_{XP})\right|} \quad (4)$$

$$\bar{Z}_T = \bar{X}_{Trunk} \times \bar{Y}_{Trunk} \quad (5)$$

where $\bar{P}$ were the coordinates of the skin markers. For the humeral coordinate system, LEP and MEP together with GH were used. The GH coordinates were confirmed by the regression parameters reported by [25]. The three axes and the origin were defined as the following, Fig. 4 (b).

$$\bar{X}_H = \frac{\bar{P}_{LEP} - \bar{P}_{MEP}}{\left|\bar{P}_{LEP} - \bar{P}_{MEP}\right|} \quad (6)$$

$$\bar{Z}_H = \frac{(\bar{P}_{GH} - \bar{P}_{MEP})\times \bar{X}_{Humerus}}{\left|(\bar{P}_{GH} - \bar{P}_{MEP})\times \bar{X}_{Humerus}\right|} \quad (7)$$

$$\bar{Y}_H = \bar{Z}_{Humerus} \times \bar{X}_{Humerus} \quad (8)$$

For the description of the angular motion of humerus relative to the trunk, a 3×3 rotation matrix R, composed of nine directional cosines of angles between axes of the humeral and trunk coordinate systems, was defined as the following:

$$R = \begin{bmatrix} \bar{x}\cdot\bar{X} & \bar{y}\cdot\bar{X} & \bar{z}\cdot\bar{X} \\ \bar{x}\cdot\bar{Y} & \bar{y}\cdot\bar{Y} & \bar{z}\cdot\bar{Y} \\ \bar{x}\cdot\bar{Z} & \bar{y}\cdot\bar{Z} & \bar{z}\cdot\bar{Z} \end{bmatrix} \quad (9)$$

where $\bar{x}$, $\bar{y}$ and $\bar{z}$ are axes of the humeral coordinate system while $\bar{X}$, $\bar{Y}$ and $\bar{Z}$ are those of the trunk coordinate system. The rotation matrix R can be also represented using three sequential rotational components, called Euler angles (ϕ_1, ϕ_2 and ϕ_3). In the present study, Euler rotation sequence (Y-Z-Y) was used to describe the rotational movements of the humerus relative to the trunk, namely the plane of elevation (ϕ_1), amount of elevation (ϕ_2) and internal/external rotation (ϕ_3), and calculated as the following:

$$\phi_2 = \cos^{-1}(\bar{y}\cdot\bar{Y}) \quad (10)$$

$$\phi_1 = \sin^{-1}\left(\frac{\bar{y}\cdot\bar{Z}}{\sin\phi_2}\right) \quad (11)$$

$$\phi_3 = \sin^{-1}\left(\frac{\bar{z}\cdot\bar{Y}}{\sin\phi_2}\right) \quad (12)$$

The maximum elevation ranges of motion in the scapular plane for different test conditions (control, sham and true treatment) were compared using Paired t-test. The significance level was set at 0.05.

3. RESULTS

The normal ROM of elevation in the scapula plane was about 180° [20]. Before any treatment in the control condition, the ROM of the shoulder in the scapular plane in the subjects with frozen shoulders was 102.91° ±24.82° (Fig. 5). The corresponding value for the sham condition was 103.90° ± 22.79° (Fig. 5). No statistically significant difference between the two conditions.

After true treatment, the ROM of the shoulder of all subjects improved from 0.55° to 35.07° with a mean of 8.34° (Table 1). Compared to control, the elevation ROM in true treatment condition (111.25° ±22°) was significantly bigger ($p<0.05$).

The ROM of arm elevation in the true treatment condition was bigger than that in the sham treatment condition. The differences in elevation ROM between the two treatment conditions ranged from 1.49° to 24.61° with a mean of 7.35° (Table 1). Compared to sham, the elevation ROM in the true treatment was significantly bigger ($p<0.05$).

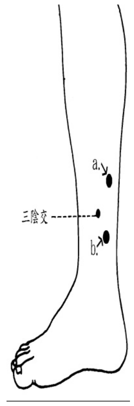

Fig 3. Positions of the sham points.

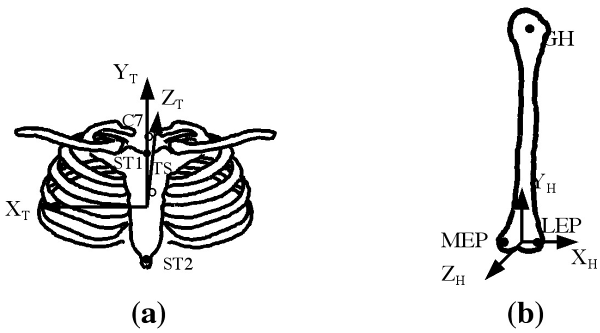

Fig 4. Definitions of the local coordinate systems of the (a) trunk and (b) humerus.

4. DISCUSSION

From the Chinese medical literature, treatment with acupuncture puncturing from Tiaokou (St. 38) to Chengshan (U.B. 57) can improve the symptoms of frozen shoulder. However, the efficacy of treatment was generally judged by subjective observations by the naked eye or by less accurate goniometers. No quantitative and scientific evidence has been reported. The present study is the first in the world that used high precision three-dimensional video-based stereophotogrammetry to evaluate quantitatively the treatment effects of acupuncture therapy of frozen shoulders.

In the present study, it was found that the sham treatment did not improve the humeral elevation angle in the scapular plane, suggesting that the test results were not affected by psychological or other factors not related to true acupuncture treatment. Treatment with acupuncture at Tiaokou (St. 38) and Chengshan (U.B. 57) increased significantly the humeral elevation ROM from 102.91° ±24.82° before treatment to 111.25° ±22° after, with a mean increase of 8.34° (Table 1). All the subjects were significantly improved. The increased elevation ROM and decreased mobility restriction in the present study verified directly the treatment effects of frozen shoulders using acupuncture described in the classical Chinese medical literature. The possible mechanism of this treatment may be because that puncturing from Tiaokou (St. 38) to Chengshan (U.B. 57) blocks the neurotransmitter of pain at the shoulder area, reducing the prohibition of muscle activation due to pain which in turn leads to increased humeral elevation. The results reported in the present study are immediate treatment effects. In order to obtain prolonged treatment effects, direct reduction of the adhesion around shoulder joint or a long-term treatment plan may be necessary. The optimum type and period of treatment require further study.

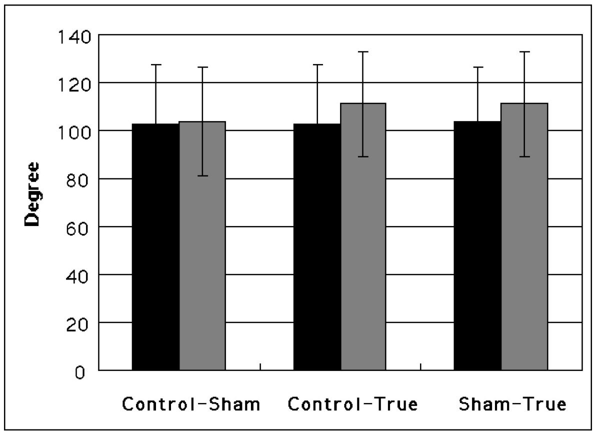

Fig 5. Pair-wise comparisons of the shoulder ROM measurements between the three test conditions (*: $p<0.05$).

Since pain affected the amount of elevation ROM quite significantly, for further study, combination of VAS (Visual Analogue Pain Scale) assessment during testing may help in studies using the present measurement technique to quantify pain at the shoulder. Simultaneous EMG measurements may also be helpful for understanding the mechanism of acupuncture treatment in frozen shoulders.

5. CONCLUSION

A quantitative and objective method using video-based stereophotogrammery system was developed to evaluate the treatment efficacy of the acupuncture by

Table 1. Pair-wise comparisons of the shoulder ROM measurements between the three test conditions.

Improvement	Control-Sham	Sham-True	Control-True
No of subjects improved	5/14	14/14	14/14
Improvement rate (%)	36	100	100
Maximum (°)	5.57	24.61	35.07
Minimum (°)	0.89	1.49	0.55
Mean (°)	0.99	7.35	8.34

inserting needle from Tiaokou (St. 38) to Chengshan (U.B. 57). It was found that, by excluding psychological effects using the sham treatment, puncturing from Tiaokou (St. 38) to Chengshan (U.B. 57) significantly increased the elevation ROM. This finding confirms the teachings described in the classical Chinese medical literature and will be helpful for the planning and implementation of long-term studies on the treatment efficacy of acupuncture in frozen shoulder.

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