Active and Passive Scapulohumeral Movement in Healthy Persons: A Comparison

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ABSTRACT. Price CIM, Franklin P, Rodgers H, Curless RH, Johnson GR. Active and passive scapulohumeral movement in healthy persons: a comparison. Arch Phys Med Rehabil 2000;81: 28-31.

Objectives: Clinical studies investigating shoulder complaints have found that active exercises and passive manipulation are not equally effective treatments, perhaps because active and passive movements align the individual shoulder girdle components differently. This study sought to investigate whether a significant difference exists in scapulohumeral rhythm of the healthy shoulder when the humerus is elevated actively or passively.

Study Design: Both shoulders of 10 healthy volunteers (9 men; mean age 50yrs) were studied using an electromagnetic coordinate system to locate the position of the scapula relative to the humerus and trunk. Scapula position in three dimensions was recorded at 10° intervals during active and passive humeral elevation in the coronal plane between 10° and 50°. Each shoulder was measured three times.

Results: Analysis of variance showed that in all three planes of scapula movement (lateral rotation, backward tip, and retraction) the components of variance attributable to the differences in active and passive movement were less than 5%.

Conclusions: During humeral elevation between 10° and 50° no significant difference exists between active and passive shoulder complex motion in healthy individuals. These findings may help to explain why passive manipulation is an effective treatment for shoulder complaints.

Key Words: Scapula; Humeral; Shoulder; Manipulation; Rehabilitation.

PAINFUL SOFT TISSUE disorders of the shoulder are common. The prevalence varies between 21% and 34% in community surveys,[1,2] which reflects the high recurrence rate and poor response to treatment in a significant number of cases.[3] Therefore, it has become necessary to examine the merits of different therapeutic approaches, guided by detailed studies of the healthy shoulder complex, to define normal parameters.

The management of a painful shoulder typically consists of three approaches,[4] which are often used in combination: (1) analgesia (including nonsteroidal anti-inflammatory drugs and intraarticular steroid injection); (2) manipulation (passive mobilization of the shoulder complex); and (3) physiotherapy (which in practice may include manipulation, but here refers to the guidance of active movement by the use of specific exercises, and the use of other physical techniques that may have additional analgesic benefit, such as temperature treatments and transcutaneous electrical nerve stimulation). Although therapy is usually tailored to the needs of the individual, a recent study found significant pain reduction after a course of passive manipulation when compared to ‘‘classic’’ physiotherapy (ie, active exercises).[5] The reason for this reduction is uncertain, since no study has previously investigated the biomechanical relationship between passive and active movement of the shoulder complex. It is unclear if manipulation reproduces the same patterns of shoulder complex movement as occur during active exercise or whether it produces a new alignment of the humerus, scapula and trunk. Therefore, comparing the effects of active and passive movement on the healthy shoulder would help in understanding the mechanism of passive ‘‘manipulation’’ techniques in the treatment of painful shoulders.

Knowledge about alignment of the scapula, humerus and thorax has been limited because it is difficult to measuring the dynamic three-dimensional movement of the scapula. The aim of the present study was to compare scapulohumeral configuration of healthy shoulders during active and passive movement using a new noninvasive technique.

METHOD

The Measurement System

Investigation of scapulohumeral alignment requires the definition of a body-based coordinate system relative to which the position and motion of the scapula and humerus can be measured. In this study the coordinates for anatomic landmarks were defined within a weak electromagnetic field around the body. A full description of the system used is given elsewhere.[6,7] Briefly, it consists of a transmitter and two small receivers, one on an adjustable plastic mounting attached to the manubriosternal joint by strong adhesive tape and positioned vertically using a bubble level included in the mounting, and the other affixed to the distal humerus by a molded polythene arm splint firmly secured by Velcro straps. Both sensors' positions are detected within the electromagnetic field, which originates from the transmitter placed over the scapula. To standardize the transmitter's position, three palpable landmarks were identified on the dorsal scapula: the acromion, the inferior angle, and the root of the scapula spine. A hand-held ‘‘Scapula Locator’’ with the transmitter attached was positioned on the skin over these three points, and the dimensions of the scapula were set using the locking mechanism of the Locator's three legs. Information from the transmitter and sensors was fed through a transducer

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Submitted for publication March 29, 1999. Accepted in revised form June 9, 1999.

Supported by a grant from The Stroke Association and a research fellowship at North Tynesdale General Hospital in association with the Department of Medicine, Newcastle University, and the Institute for the Health of the Elderly, Newcastle upon Tyne.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the authors or upon any organization with which the authors are associated.

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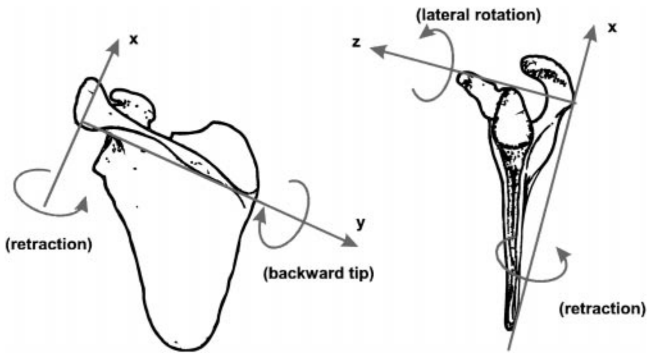

Fig 1. Definition of scapula axes.

(the two-channel 3SPACE™ IsotrakII™ system[a]) to a portable computer. Specialized software displayed in real time the position of the scapula and humerus relative to the receiver mounted on the sternum. This configuration provided detailed three-dimensional data about the alignment of the scapula in relation to the arm and trunk at a given time.

While the humerus was elevated, the observer followed the scapula's position with the Locator, keeping its three reference points aligned. Before another data set was recorded the observer took 1 to 2 seconds to check that the Locator remained in contact with the bony landmarks and that skin elasticity did not cause it to lag behind during scapula rotation. Although this hand-held Locator method could potentially be flawed by difficulty in palpating landmarks and by artifact from skin motion, it is a portable noninvasive alternative to radiography or fixation of bony markers that has a high level of interobserver and intraobserver reliability in healthy subjects.[7]

Three rotational movements of the scapula were then defined within horizontal, vertical and anterior-posterior planes: backward tip, retraction, and lateral rotation (fig 1). To account for anthropometric differences between subjects, standard Euler angle rotations were determined in the coordinate frame of the scapula at rest.[8] All measurements of scapula motion were then directly comparable.

The Standard Test

Subjects were seated with their arms relaxed to the side at 0° of elevation and flexion. For active movement, subjects elevated the arm under examination in the coronal plane from 10° to 50° in 10° increments. At each increment, the Locator was applied and a record of scapula position taken. During passive movement the subject was asked not to assist while a researcher abducted the arm in the coronal plane, supporting the elbow and midhumerus with two hands, while a second observer took readings at 10-degree intervals.

Elevation of the arm only took place over a small range of motion (10° to 50°) to ensure that the humerus did not impinge on the coracoacromial arch and to reduce the possibility of the scapula being "dragged" upwards by raising the humerus. Since ligaments only act at the extremes of motion we believed that they would not influence motion within this range. Observers were blind to the readings during each test. Ethical approval for the study was obtained from the local ethics committee.

Subjects

We advertised for volunteers among the staff in a local hospital and relatives of patients attending for physiotherapy. Subjects were required to have no history of any joint disease or injury, and a shoulder motion that appeared clinically normal, with painless active and passive humeral abduction to 160°. The intrasubject variation of active scapula rotation during pilot work was small enough that 10 subjects measured twice actively and twice passively was calculated as sufficient data to ensure a 90% chance of detecting a difference of >5% between active and passive motion. We took three data sets from each shoulder during each mode of humeral elevation to ensure adequate data for analysis.

Data Analysis

A four factor mixed model analysis of variance (ANOVA) design was employed, in which the subjects were assumed to be the random factors, and the mode of humeral elevation (active or passive), shoulder side (left or right) and scapula positions were fixed factors.[7,9] Using such a model, it is possible to apportion components of variance to each factor and identify the degree of system error—that is, the disagreement between factors that cannot be explained other than by variation within the process of taking repeated measures. Factors not contributing towards much variation in results must each have components smaller than the system error. The components are expressed as a percentage of overall variation. The level of statistical significance is set at 5% (ie, a factor with a component of variance of less than 5% is unlikely to represent a significant source of variation within the results). For lateral rotation of the scapula, the component of variance for the individual subjects was also determined by using a three factor fixed model ANOVA.

RESULTS

The left and right shoulders of 10 volunteers (9 men, 1 woman, with a mean age of 50yrs [age range 17 to 78yrs]) were examined three times during active and passive movement. Therefore, 60 sets of measurements were obtained for each mode of humeral elevation. Each set consisted of 5 readings (10° to 50°). Analysis was undertaken on a total of 600 readings. No subjects experienced any discomfort during the tests.

Figures 2 through 4 show mean values and 95% confidence intervals for scapular lateral rotation, backward tip, and retraction, respectively, over the range of humeral abduction tested. Table 1 reports the results of the ANOVA, showing the components of variance arising from the differences between subjects, their left and right sides, and passive or active motion of the shoulder. For lateral rotation the differences between subjects are the largest source of variation. System error is the

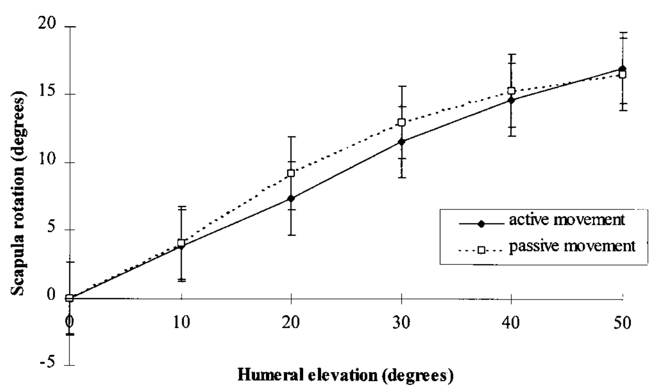

Fig 2. Scapula lateral rotation against humeral elevation during active and passive elevation of the arm.

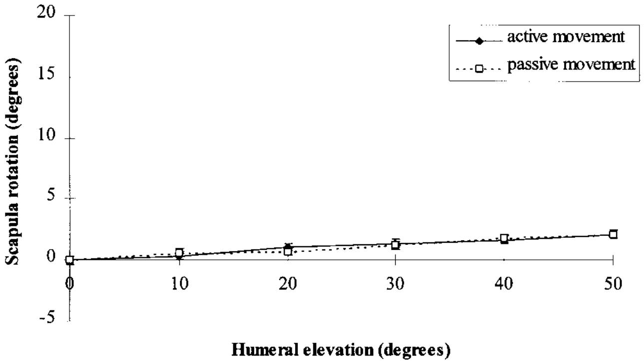

Fig 3. Scapula backward tip against humeral elevation during active and passive elevation of the arm.

Table 1: Components of Variance for All Subjects Combined

	Variance Components (%)			
	Intersubject Variation	Passive/Active Motion	Left/Right Shoulder	System Error
Scapula motion				
Lateral rotation	22	<1*	<1*	7
Backward tip	5	<1*	6	22
Retraction	16	4*	<1*	14

* $p < .05$.

main source of variation for the backward tip and retraction movements. In comparison, the mode and side of humeral abduction are small effects. Table 2 reports the ANOVA results for each subject during scapular lateral rotation, showing the components of variance arising from the differences between the sides and mode of humeral elevation. Again, these results are never greater than the system error encountered during repeated measures.

DISCUSSION

This study demonstrated the use of a noninvasive system to measure shoulder complex motion during both active and passive abduction of the arm in the coronal plane. The results indicate that between 10° to 50° of humeral abduction, the mode of elevation (active or passive) is responsible for very little variation in scapulohumeral alignment. The natural variation between individuals and the system error during repeated measures are considerably larger sources of variance.

When active and passive motion are compared, retraction shows the largest component of variance, but even this value of 4% is much less than the component due to system error and intersubject variation. During rotation within the other two planes, the variance component is less than 1% of the total. Since all three components are less than 5% of the total variance, it can be concluded that there is no significant difference in scapula motion with active or passive motion between 10° and 50° of humeral elevation.

The variation between subjects found here is not unusual, and is comparable with other studies using this system.[7,10] Scapula motion appears to vary between individuals, and there is not a single common pattern of rotation within this sample. The inclusion of elderly and young subjects may be partly responsible for this intersubject variation, since even in the absence of previous shoulder complaints elderly subjects are likely to have a more restricted shoulder complex movement and less muscle bulk. The lone female volunteer could be another source of intersubject variation; however, we did not expect either the potential gender or age effect to be significant confounding factors in the subsequent intrasubject comparison of active and passive motion.

For each participant, lateral rotation was chosen for the analysis because it is the largest scapula movement. The mode of humeral elevation never had a component of variance greater than the system error. The similarity in lateral rotation during active and passive movement reached the level of 5% significance for eight subjects. The remaining two subjects still had a level of less than 10%, and since their system error is particularly large, it is possible that technical factors (such as environmental metal interfering with the electromagnetic field) or observer error (such as difficulty in palpating Scapula Locator landmarks) prevented the 5% level being reached. System error becomes more significant when results are analyzed for the individual, since there are fewer measurements.

The mechanism that positions the scapula appropriately during passive mobilization is unclear, but to achieve such a close replication of those patterns shown during active movement, it is likely to be a coordinated response by the muscles attached to the scapula rather than simply as a result of traction. “Dragging” of the scapula during passive humeral elevation would be unlikely to position it in very nearly the same three-dimensional alignment as active movement. Instead it is more likely that local reflexes react to proprioceptive information from the passive stretching of tendons and joint capsule, and that the uniformity of scapula positioning is an active, organized process. Electromyographic (EMG) studies support this theory, demonstrating that although rotator cuff muscle activity is greater during active exercises against resistance

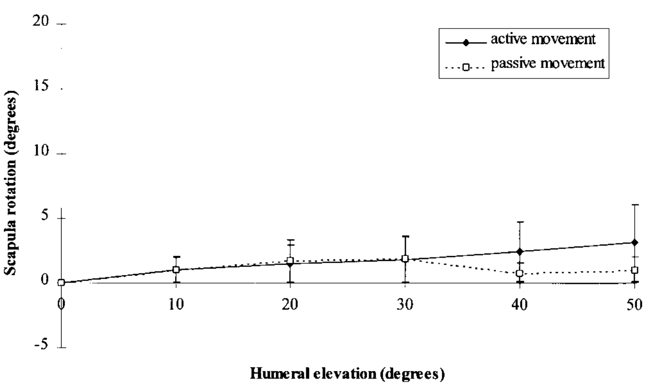

Fig 4. Scapula retraction against humeral elevation during active and passive elevation of the arm.

Table 2: Components of Variance for Each Subject (Scapula Lateral Rotation)

	Component of Variance (%)		
Subject	Passive/Active Motion	Left/Right Shoulder	System Error
1	1	<1	5
2	<1	<1	5
3	3	2	4
4	7	17	23
5	5	<1	5
6	<1	1	5
7	9	2	12
8	2	<1	5
9	4	<1	11
10	<1	<1	10

EMG activity is ongoing during passive motion assisted by a therapist[11] or a continuous passive motion machine.[12]

In the present study measurements were taken in the passive mode only after the researcher felt that she was holding the full weight of the subject's arm, but we remained reliant upon the abilities of the volunteers to relax fully. The effects of complete muscle relaxation have been examined in previous studies that used anatomical sections from cadavers to investigate changes in glenohumeral alignment during joint loading. It appears that active rotator cuff force contributes significantly to stabilization of the glenohumeral joint, and the joint may not be as stable during passive motion that relies more upon capsular constraints.[13,14] Larger humeral translations occur during passive positioning, suggesting that some caution is needed during manipulation to avoid abnormal joint conformity. However it is important to recognize that specimens in a laboratory setting are unlikely to reflect all physiologic mechanisms, particularly because of the difficulty in recreating scapulothoracic movement and the loss of constant background muscle activity demonstrated in EMG studies. A need exists for further clinical studies using noninvasive techniques of motion analysis.

Findings of the present study help to clarify why passive manipulation of the shoulder complex has additional benefits when compared to active exercise programs in certain types of soft tissue disorder.[4] When voluntary muscle contraction is painful (as commonly occurs in rotator cuff tears, supraspinatus tendinitis or early after capsular surgery) passive movement can keep the joint fully mobile by closely replicating the way that the shoulder complex is organized during active motion. This procedure could prevent further restriction of shoulder movement from adhesions, which may become a dominant factor if pain prevents exercise.[15] When capsule strength improve or pain subsides, active and then resistive exercises can be introduced gradually,[11,12] thereby facilitating the recovery of normal function with the passive preservation of shoulder girdle movement. It may not always be appropriate to use passive exercises, since they will not contribute directly towards the muscle strengthening that is an essential component of recovery. When pain threatens to restrict shoulder movement, however, our results suggest a scientific basis for using careful passive manipulation to start the rehabilitation process. For confirmation, an investigation of shoulder complex motion in patients undergoing active and passive mobilization programs will be needed.

The rationale behind treatment of the shoulder joint by passive manipulation has particular relevance to the rehabilitation of hemiplegia following stroke. This measurement technique has found a significant relationship between scapula motion patterns and shoulder pain 6 months after stroke,[16] but so far evidence is insufficient to make recommendations about active and passive movement during mobilization of the upper limb.[17] Physiotherapy generally is believed to reduce painful restriction of the shoulder, although the published evidence has been inconclusive.[18,19] It may now be appropriate to reassess the role of passive upper limb mobilization in stroke rehabilitation, which has been viewed by some as responsible for hemiplegic shoulder pain rather than as a method of pain prevention.

CONCLUSION

During repeated measures of scapulohumeral alignment in a population of healthy volunteers we found no significant difference in scapula motion during passive and active humeral elevation. Careful passive manipulation treatment may have an effect through replication of the scapulohumeral alignment that is adopted during active exercise, although evidence from anatomical specimens suggests that the joint may not be as stable without the active rotator cuff activity. We recommend that noninvasive systems be used in further studies concerned with therapy for painful soft tissue disorders of the shoulder, in order to establish the roles of various treatment approaches.

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