Levator Scapulae Action during Shoulder Movement: A Possible Mechanism for Shoulder Pain of Cervical Origin

The phenomenon of shoulder pain of cervical origin being reproduced on shoulder movement is clinically recognized. The action of the shoulder girdle muscles is a hypothetical cause of the cervical stress.

This study examined the mode and degree of Levator Scapulae activity during shoulder activity. Electromyography and x-rays were used to measure levator scapulae activity and length. The results of the study show that levator scapulae contracts concentrically during the first 90 degrees of shoulder abduction and eccentrically during the second 90 degrees.

The action of levator scapulae may be responsible for the application of force on the cervical spine during shoulder abduction. This force might cause cervical joint tissue distortion and pain if a pathological state was present.

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The incidence of distally referred pain arising from irritation of vertebral structures is a well documented phenomenon (Kellgren 1939, Cloward 1959, Hockaday and Whitty 1967, Mooney and Robertson 1977, McCall *et al* 1979). The clinical picture of a patient presenting with shoulder pain which is reproduced on certain activities of the shoulder, but which, on a more thorough examination, is revealed to have a cervical origin is common (Cinquegrana 1968, Maigne 1975, Maitland 1975, Cyriax 1978, Wells 1982).

Cyriax (1978 p226) and Bogduk (1983) have hypothesized that the action of the shoulder girdle muscles on the cervical spine has a role in producing the referred shoulder pain of cervical origin on shoulder movement. These hypotheses were made without reference to data. A review of the literature has not revealed studies which have established the mechanics wherein shoulder movement could produce stress on the cervical joints and thereby cause the referred symptoms in the shoulder. Elvey (1980) has described a mechanism of cervical nerve root tension resulting from shoulder movement. This mechanism does not account for those patients who have negative nerve root signs and symptoms of purely cervical joint origin.

Muscle actions over a joint produce forces which may result in movement but also create compressive forces between the joint surfaces (White and Panjabi 1978). During active shoulder function, cervical movement may be prevented by synergistic muscle actions over that area, but unobservable compression forces may still be produced. Scientific studies (Howe *et al* 1977, Shah *et al* 1978, Rydevik *et al* 1984) and clinical observations (White and Panjabi 1978, Maitland 1980) indicate that compression, especially when asymmetrically applied, can produce joint tissue or radicular distortion and thereby stress and pain. It was found that there was an apparent lack of reliable data on the possible mechanical cause of shoulder pain of cervical orgin produced by shoulder movement. This led to a decision to examine studies on the shoulder girdle muscles to assess whether a possible mechanism for the production of stress and pain lay in their action.

A number of studies have examined shoulder girdle muscle activity electromyographically (Inman *et al* 1944, Yamshon and Bierman 1948, DeFreitas *et al* 1979, 1980, Hagberg 1981) but none are definitive due to methodological flaws. No studies were found which examined the mode of contraction (*ie* concentric, eccentric or isometric) of the shoulder girdle muscles.

It was felt that further study of the behaviour of the shoulder girdle muscles was required to assess their possible role in relation to shoulder pain of cervical origin. Levator scapulae was selected for this study because it directly connects the cervical spine to the shoulder girdle and because its fibres have a discrete pattern of alignment, allowing for tidy biomechanical assessment.

It is generally believed that with the cervical spine fixed, levator scapulae acts to elevate the scapula and downward rotate it, *ie* the glenoid cavity being turned caudally. With the scapula fixed, acting unilaterally, levator scapulae is believed to laterally flex and rotate the vertebrae ipsilaterally: acting bilaterally, it is believed to assist in cervical extension (Kendall and McCreary 1983).

DeFreitas *et al* (1979, 1980) studied levator scapulae using needle electromyography (EMG) during shoulder movement but lack of methodological data, including the exact location of the EMG electrode, made their results questionable.

Inman *et al* (1944) are often cited for their description of shoulder girdle muscle function including that of levator scapulae (*ie* by Basmajian 1978 and Norkin and Levange 1983), but examination of the original paper revealed a lack of any data concerning levator scapulae activity.

Inman *et al* (1944) and Dvir and Berme (1978) have described scapulothoracic movement during shoulder activity but a lack of methodology and data in the former paper and the small amount of data presented in the latter (*ie* the results from one subject) make these descriptions unreliable.

This study was undertaken to assess the EMG activity of levator scapulae during shoulder movement and to determine the mode of contraction and length of the muscle during these movements by way of measurement from x-rays.

This data was combined to assess how levator scapulae behaves during shoulder movements and whether its action could be responsible for the production of stress on the cervical spine.

Method

EMG Examination of Levator Scapulae during Shoulder Movement (Method A)

Seven volunteers, four male and three female, with an average age of 27 years (range 24-29 years) were studied electromyographically to observe the pattern of levator scapulae firing during shoulder activity. Before commencing the procedure, informed written consent was obtained from all subjects.

A Medelec MS6 MkIII system was used to record the EMG activity. The apparatus was set at a gain of 500μV/division, a sweep speed of 10 millisec/division and for a frequency range of 16-16,000 Hz. The paper recorder was set at 2 cm/sec.

A single coaxial needle electrode (2.5cm long in five subjects and 5.0cm long in the other two) was used to pick up the muscle activity. The subject was earthed by a reusable rubber surface electrode placed over the scapula on the test side.

The needle electrode was inserted in the right side at a point formed by the insertion of a horizontal line passing through the T1 spinous process with a vertical line passing one centimetre medial to the superior angle of the scapula (Figure 1). The electrode was inserted at a depth between 2.0 and 2.5 cm. This site was based on the results of cadaveric measurements of trapezius thickness and levator scapulae position and of skin/fat thickness in the EMG volunteer subjects. These measurements indicated that this site and depth was the most reliable to ensure electrode placement into the belly of levator scapulae (Behrsin 1984).

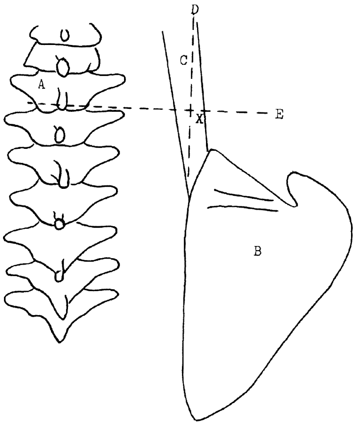


Figure 1: Determination of the electrode site.

A	First Thoracic vertebrae
B	Scapula
C	Levator Scapulae
D	Vertical line one centimetre medial to the superior angle of the scapula
E	Horizontal line through T1
X	Electrode site

The testing was carried out in an electrically screened room to minimize extraneous electrical noise.

In an endeavour to replicate the common clinical test procedures, the subjects were examined in standing. Before each recording the subjects were requested to relax their arms to obtain electical silence.

The movements of resisted right shoulder girdle elevation and resisted shoulder extension/adduction were performed to establish needle location and function. These responses were noted but not recorded.

The following movements were then performed and recorded:

1. Free right shoulder abduction through full range with the arm in neutral rotation.

2. Free right shoulder flexion through full range with the arm in neutral rotation.

3. Maximal resisted right shoulder isometric abduction in five degrees abduction starting position.

4. Free left shoulder abduction through full range with the arm in neutral rotation.

5. Free right shoulder external rotation in neutral flexion/extension with the elbow flexed 90 degrees.

The full range movements were performed at a prerehearsed rate of approximately 60 degrees per second.

The resultant EMG recordings were then graded using the system described by Basmajian (1978). In this system the degree of EMG activity is visually graded. The gradings are: 0, where there is no activity; 1+ where there is minimal activity (1-25% of maximal activity); 2+ where there is mild activity (26-50% of maximal activity); 3+ where there is moderate activity (51-80% of maximal activity) and; 4+

where there is strong activity (81-100% of maximal activity). This study used the activity observed during resisted shoulder girdle elevation as the basis for grading (*ie* the 100% value) as this always produced the strongest EMG response. Due to the limitations of this system descriptive comments on the EMG activity of some movements has been included in the results.

X-ray Assessment of Levator Scapulae Length during Shoulder Abduction (Method B)

Plain A/P view x-rays of the upper quadrant were taken to include the right glenohumeral joint, the scapulo-thoracic joint and the vertebrae from C5 to T10. X-rays were taken with the shoulder actively abducted at 0, 90 and 170 degrees with the subject standing.

Two subjects were used, one female aged 24 and one male aged 28 years. Both had been subjects for the EMG study (Method A).

Using the spinous process of T1 and T4 as common reference points, tracings of the scapula were performed from the x-rays, superimposing the three positions.

Measurement from the subjects C1 to T1 spinous process and the width of C1 were taken in vivo. These distances were corrected for the distortion due to the distance from the x-ray plate by multipying by k, using the formula

$$k = \frac{\text{T1 to T4 on x-ray}}{\text{T1 to T4 in vivo}}$$

and then placed on the tracing of scapula positions.

The relative distance of C1 transverse process to superior angle of scapula was then measured for the three positions and these figures corrected by dividing the result by the x-ray distortion factor, k.

The values for the different scapula positions were then estimated as percentage values of the resting value *ie* the length with the shoulder at 0 degrees. These values are assumed to indicate the length of levator scapulae at different shoulder abduction positions.

The instantaneous axes of rotation for the scapula motion between 0 and 90 degrees and 90 and 180 degrees of shoulder abduction were determined by using the method described by White and Panjabi (1978 p479). A common point (*ie* the inferior angle of the scapula) on two sequential scapula positions was joined by a line which was then bisected by another line at right angles. This procedure was repeated using several reference points. The intersection of the bisecting lines was taken as the instantaneous axis of rotation for that movement.

Results

A: The graded responses to the test movements as recorded by EMG are shown in Table 1.

Maximal activity was observed during resisted shoulder girdle elevation in all seven subjects, while minimal or no activity was observed during resisted shoulder extension/adduction.

Three subjects showed minimally greater activity on free abduction of the right arm compared with resisted abduction. The other four subjects showed the reverse.

During free shoulder abduction on the right side there was a slight observable increase in activity during the second half of range (ie 90-180 degrees) to that seen in the early half of range.

EMG activity was next greatest during flexion. The intensity of activity varied from 50 to 80 percent of that observed during free right shoulder abduction, except in one subject where it was only minimally active. In three subjects there appeared to be a gradual slight increase in activity during the outer range of flexion. This was not observed in the other four subjects.

EMG spikes due to needle movement were most commonly recorded on the movements of right shoulder abduction and flexion through range. During one subject's recording there appeared an underlying interference pattern which was found to be due to slight loosening of the earth electrode.

Table 1:
EMG activity in right levator scapulae

Movement	*Grade 0*	*Grade 1+*	*Grade 2+*	*Grade 3+*	*Grade 4+*
Right free Abduction (0-90 degrees)				4	3
Right free Abduction (90-180 degrees)				1	6
Right free Flexion (0-90 degrees)		1	5	1	
Right free Flexion (90-180 degrees)		1	3	3	
Right res. Abduction					7
Left free Abduction *	1	5	1		
Right Ext. Rotation *	3	4			

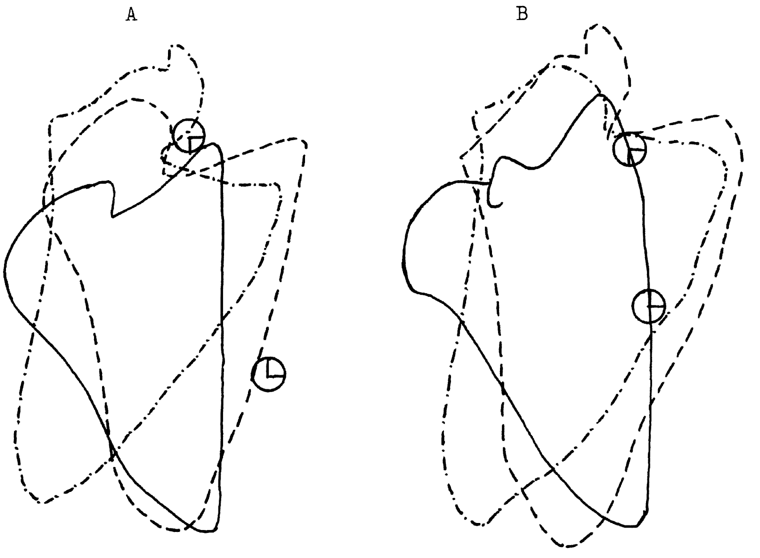
* Range not included as no significant changes occurred through range.

B: Tracings of the subject's scapular positions during shoulder abduction taken from x-rays are presented in Figure 2 along with the instantaneous axes of motion.

The x-ray distortion was calculated at 1.03 for the male subject and 0.93 for the female.

The results for the C1 transverse process to superior angle of the scapula distances are set out in Table 2. These results are given as the actual distances (*ie* they have been recorrected from the x-ray data) and as percentage values of the resting length.

The data indicates that levator scapulae undergoes shortening during the first half of abduction but undergoes lengthening during the second 90 degrees of shoulder abduction in these two subjects.



Legend for Figure 2

A	Scapular positions for subject A
B	Scapular positions for subject B
————————	Scapula at 0 degrees shoulder abduction
- - - -	Scapula at 90 degrees shoulder abduction
- · - · -	Scapula at 170 degrees shoulder abduction
◷	Instantaneous axis of rotation for 0 — 90 degrees abduction
◶	Instantaneous axis of rotation for 90 — 170 degrees abduction

Figure 2:
Tracings from x-rays of subject's scapular positions during shoulder abduction.

Discussion

DeFreitas *et al* (1979, 1980) found in their EMG study of levator scapulae that it was strongly active in abduction and elevation, moderately active in shoulder flexion and minimally active in scapular retraction and shoulder extension. Those results are in agreement with those of this current study in which some of the methodological flaws of DeFreitas *et al* (1979 1980) were rectified. This study also found that levator scapulae activity increased in the outer range of flexion and abduction in some subjects, a finding not previously noted.

Inman *et al* (1944) and Dvir and Berme (1978) described different phases of scapulo-thoracic movement during shoulder abduction and flexion. These phases are a result of interaction between shoulder girdle muscle activity, sternoclavicular and acromioclavicular joint motions, and ligament tension. The phases, briefly, are:

Phase One, setting (between 0 and 30 degrees abduction and 0 and 60 in flexion), in which the scapula is aligned for optimal glenohumeral movement.

Phase Two (between 30 and 90 degrees abduction and 60 and 90 degrees in flexion) in which the scapula rotates around an axis approximately passing through the root of the spine of the scapula and the sternoclavicular joint.

Phase Three in which the scapula as a whole rotates about an axis at the acromioclavicular joint.

Phase Four in which the scapula and clavicle move as a unit about the long axis of the clavicle. Phases three and four account for the ranges of 90 to 180 degrees in flexion and abduction.

This current study found that the movement of the scapula relative to the spine in the first 90 degrees of shoulder abduction was quite different to that described by Inman *et al* (1944) and Dvir and Berme (1978). Rather than rotating about an axis through the root of the spine of the scapula, the rotation occurred through a point closer to the centre of the scapula near its medial border. Also, contrary to the

Table 2:
Relative distance of C1 transverse process to superior angle of scapula

		cm	*% of Resting Length*
Subject A	0 Degrees	13.4	100
	90 Degrees	12.0	89
	170 Degrees	14.5	108
Subject B	0 Degrees	14.0	100
	90 Degrees	13.1	94
	170 Degrees	14.2	101

Dvir and Berme (1978) paper, there was significant movement of the root of the spine of the scapula during the first 90 degrees.

During the second 90 degrees of abduction the root of the spine of the scapula was found to move downwards and laterally. This is in agreement with Dvir and Berme (1978), but the degree of the movement was not as great as their paper seemed to indicate.

These differences in scapular movement may be normal variations of scapulo-thoracic motion. A larger study needs to be undertaken to clarify this question.

The calculated measurement of levator scapulae length during shoulder abduction indicates that this muscle shortens during the first 90 degrees and lengthens during the second 90 degrees (*ie* to full elevation).

If all the data concerning levator scapulae behaviour are combined, it can be concluded from this study that levator scapulae contracts concentrically during the first half of abduction and eccentrically during the second half of abduction. The force produced by an eccentric contraction of the same intensity of activity is greater than that produced by a concentric contraction (DeLauter 1982). This indicates that the force exerted by levator scapulae is greatest during the second half of abduction range. This force would be even greater in those individuals exhibiting an increase in EMG activity in the outer range of movement.

In one subject, whose relative length of levator scapulae during different abduction positions was assessed, there was an actual increase in levator scapulae length at full elevation compared to that at rest (*ie* 108%). As passive tension due to a muscle being stretched can produce force (DeLauter 1982), this force should be considered additive to that being produced by the eccentric contraction of levator scapulae.

As levator scapulae exerts an increasing amount of force on the cervical spine during outer range shoulder abduction, an increase in loading on the cervical joints must occur. From the vector components of the action of levator scapulae on the cervical spine (Figure 3), it can be seen that levator scapulae loading will result in compressive loading, but will also have a tendency to laterally flex and rotate the spine ipsilaterally.

In most cases, there is minimal movement of the cervical spine indicating that synergistic muscle action is occurring to isolate levator scapulae action to the scapulo-thoracic joint. The results at the cervical spine may be then an increase in compressive loading which will result in increased intradiscal pressure and increased apophyseal joint surface imbrication. It can be speculated that some degree of apophyseal joint gliding occurs concurrently with intervertebral disc distortion.

The stress produced on the cervical spine by levator scapulae has the potential of producing tissue distortion, especially if abnormal states exist in the joints. This distortion may produce a pain response, including the production of referred pain which may be experienced in the shoulder.

It is likely that the interaction of other synergistic muscles is important in considering the production of shoulder pain of cervical orgin on shoulder movement. The anatomical alignment of levator scapulae and its eccentric behaviour during shoulder movement indicate that it may have a significant role in the phenomenon.

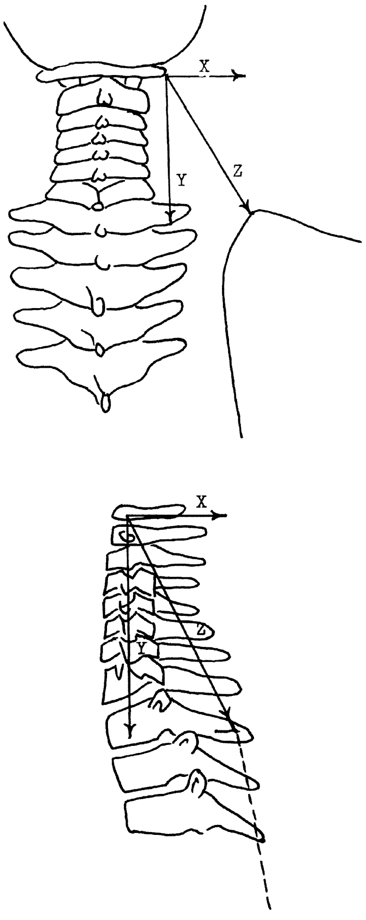


Figure 3: The vector components of the action of levator scapulae on the cervical spine.

Z Vector for Levator Scapulae action
X Horizontal component of Levator Scapulae action
Y Vertical component of Levator Scapulae action

Conclusion

The EMG results and estimated lengths of levator scapulae during different parts of active shoulder abduction range indicate that levator scapulae contracts concentrically during the first 90 degrees and eccentrically during the second 90 degrees.

Due to the different amount of force generated by these two types of contraction, it appears that levator scapulae exerts greater force during the outer range of shoulder adbuction. This force can act on the cervical spine via the muscle's cervical attachment.

It is suggested that the potential stress on the cervical spine due to levator scapulae action, which increases in outer abduction, may, in the presence of pathological changes, cause pain. Levator scapulae action may be a potential mechanism for shoulder pain of cervical origin during active shoulder movement.

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