Arm abduction angle and contraction intensity effects on deltoid and scapular rotator muscle recruitment during scapular plane isometric contractions

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Purpose: To investigate the effects of arm elevation angle and voluntary isometric contraction intensity on deltoid and scapular rotator muscle recruitment.

Methods: Nine healthy, young adults (5 men, 4 women) performed maximal and sub-maximal isometric arm abduction contractions in the scapular plane on a Biodex isokinetic dynamometer. The subject's right arm was secured to the resistance arm of the dynamometer immediately proximal to the wrist. The arm was positioned in the plane of the scapula in an abducted position. Subjects performed five isometric maximal voluntary abduction contractions (MVCs), followed by randomly ordered ten-second sub-maximal contractions at 10-90% MVC (10% increments) (CI), at the following arm abduction angles (AA): 15, 30, 45, 60, 75 and 90 degrees.

During each contraction electromyograms (EMG) were obtained from the deltoid (DEL), upper trapezium (UT), lower trapezium (LT) and serratus anterior (SA) muscles. EMG signals were collected at 2000 Hz, bandpass filtered (20-500 Hz) and fullwave rectified. A 3 second analysis window was chosen during the point of maximal torque for the MVC's and during the point at which the subject was producing the target torque. The integrated EMG (IEMG) value was calculated for each analysis window, and were expressed in absolute (ABS) and normalized to the MVC (NORM) units.

Results and Discussion: The MVC torque (TOR) decreased significantly ($F_{5, 40} = 7.44$, $p<0.001$) as AA increased (Table 1). Absolute IEMG demonstrated significant main effects for AA ($F_{5,160} = 15.82$, $p<0.001$) and CI ($F_{9,288} = 171.79$, $p<0.001$).

Analysis of the NORM IEMG demonstrated significant main effects for both AA ($F_{5,160} = 15.18$, $p<0.001$) and CI ($F_{8,256} = 637.15$, $p<0.001$), and an AA by CI interaction ($F_{40,128} = 5.82$, $p<0.001$). The lower AA levels (15, 30, and 45 deg) were each significantly different from the higher AA levels (60, 75, and 90 deg). No significant muscle main effect or interaction effects were observed to be significant. Figure 1 displays the normalized IEMG as a function of CI for the DEL muscle (only the 15, 45 and 90 deg levels are shown for clarity). A similar pattern of higher NORM IEMG, plotted as a function of CI, was shown for the UT, LT and SA muscles.

The results of this investigation agree with the results from previously reported studies. Lawrence and DeLuca (2) reported a nonlinear increase in EMG intensity with increasing CI. Coury et al (1) reported an increase in deltoid EMG and a decrease in deltoid force with increasing shoulder flexion. Ringelberg (3) reported that normalized IEMG increased during sub-maximal isometric contractions, as a function of increasing AA. EMG from the upper trapezius has been shown to display a linear increase with increasing CI; however the rate of EMG increase was greater during higher force contraction, 50-90% MVC than lower force contractions (4).

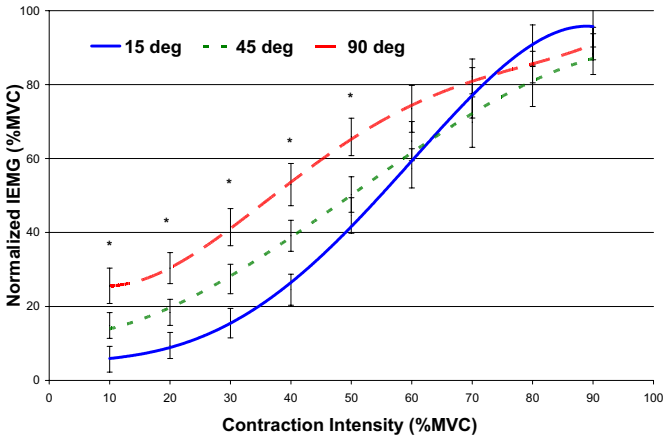

Figure 1. Normalized deltoid muscle IEMG vs. CI, 15°, 45° and 90° AA (*p<0.05).

Conclusions: The results of this investigation demonstrate that the recruitment of the shoulder muscles during isometric abduction contractions is dependant upon the position of the shoulder, as well as the intensity of the contraction. The increased muscular recruitment that is exhibited at higher AA during relatively low CI is possibly explained by changes in muscle length produced by altering orientations of the bony components of the shoulder girdle.

References:

1. Coury HG, et al. *J Electromyogr. Kinesiol,* **8** 157-168, 1998
2. Lawrence JH and DeLuca CJ, *J Appl Physiol* **54** 1653-1659, 1983
3. Ringelberg JA, *J Biomech* **18** 939-947, 1985
4. Hagberg C and Hagberg M, *Eur J Appl Physiol* **58** 641-645, 1989

Table 1. MVC torque and IEMG.

	15 deg	30 deg	45 deg	60 deg	75 deg	90 deg
Torque (N•m)	55.2 (7.7)	54.1 (7.5)	49.9 (6.7)	48.1 (7.0)	45.4 (6.9)	45.7 (8.3)
Deltoid (V•s)	3.468	3.45	3.611	3.884	3.862	3.78
Upper Trapezium (V•s)	1.903	2.775	2.558	2.988	3.199	3.165
Lower Trapezium (V•s)	1.914	1.92	1.719	1.75	1.95	1.867
Serratus Anterior (V•s)	0.84	0.783	0.967	1.102	0.906	1.117