

# An Electromyographic Study of Coactivity of Human Extraocular Muscles in Following Movements

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Cocontraction is defined as the simultaneous increased contraction of extraocular muscles which are normally antagonistic in their primary field of action. It has been hypothesized that cocontraction occurs when the eye moves from its primary position to any secondary or tertiary position.<sup>1</sup> According to this hypothesis, as the lateral rectus abducts an eye, the vertical recti as well as the obliques cocontract to steady the eye in its horizontal path. At the same time, the cocontraction prevents undue torsion of the globe and helps maintain abduction as the lateral rectus loses its mechanical advantage as the movement progresses. The same reasoning would apply to adduction, supraduction, and infraduction. It is the purpose of this paper to report the results of testing this hypothesis by multiple-channel electromyography.

The steadying effect and reinforcement of eye movement by cocontraction of auxiliary muscles\* was postulated as early as 1897 by Duane.<sup>2</sup> By constructing muscle planes and moments of rotation, Verrijp<sup>3</sup> shows the effect of auxiliary muscles in various movements. He believes that muscles other than the prime mover and its antagonist steady the movement and keep the vertical axis from torting. Krewson<sup>4</sup> calculated mathematically the action of all the extraocular

muscles in various positions of horizontal gaze by a method of vector analysis. According to this analysis, the vertical recti and obliques are in a position to contribute to internal and external rotation of the eye by cocontracting during horizontal movements. This contribution is greater or lesser depending on the horizontal position of the eye at the time of cocontraction. Gordon<sup>5</sup> cut the vertical recti and found adduction diminished in the immediate postoperative period. After a number of days, full adduction returned, which Gordon interpreted as indicating reattachment of the vertical recti, so that they again could aid in accomplishing normal maximum internal rotation. It is possible, however, that the return of full adduction signified recovery from post operative reaction. Swan<sup>6</sup> studied the horizontal effect of vertically acting muscles when both the medial and lateral rectus muscles were tenotomized in humans under topical cocaine and subconjunctival procaine anesthesia. He found that the vertical muscles had adductive force limited to a few degrees when movement was initiated from the primary position. One of us (A. J.) found that under topical anesthesia only at least half the normal amplitude of adduction and abduction was still available when the medial and lateral rectus muscles and attachments were cut on the operating table. Chamberlain<sup>7</sup> found in the rhesus monkey that the vertical recti and the obliques are of very minor importance in horizontal rotation so long as the primary rotators (horizontal) are intact.

Multiple-channel electromyography affords a more direct method of testing the

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\*By auxiliary muscles, we mean those extraocular muscles other than the prime mover (agonist) and its direct antagonist.

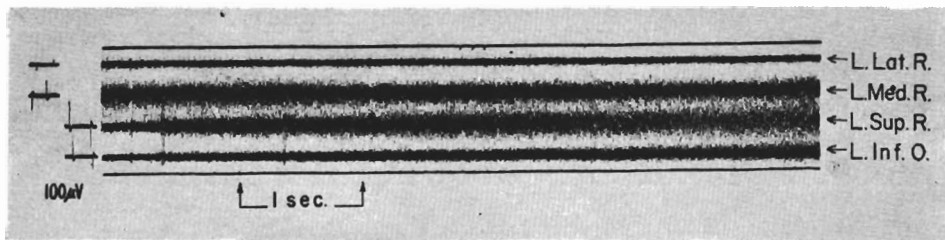


Fig. 1.—Up gaze in sagittal plane of left eye. In all Figures the top line is the signal marker, the bottom line is the time marker, and calibration is at the left. Note no obvious change in horizontal recti.

above hypothesis. We can record the electrical activity of four extraocular muscles simultaneously. The details of the technique have been previously reported.<sup>8</sup> Over the past two years, the findings in scores of patients have been recorded. This paper will deal with electrical coactivity in horizontal and vertical following movements in the plane of the primary position. Although it is widely believed that the recorded electrical

A. Up gaze. In Figure 1 there is movement of the left eye straight upward in the sagittal plane. There is increasing electrical activity of the two vertical movers, the superior rectus and the inferior oblique, but no obvious change in the recording of the activity of the lateral and medial rectus muscles.

B. Down gaze. Figure 2 is the electromyogram of a downward movement of the left

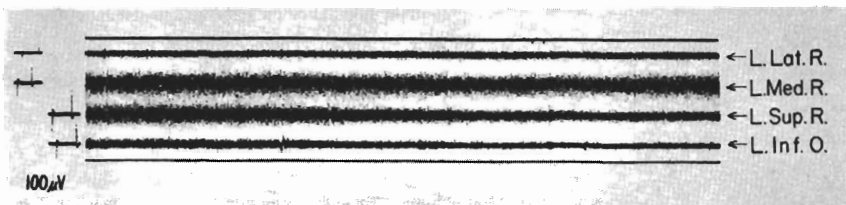


Fig. 2.—Down gaze in sagittal plane of left eye. No measurable change in horizontal recti.

activity is correlated with muscle contraction, we prefer to use the term “electrical coactivity,” because this is actually what we are measuring. All movements shown were approximately 50 degrees in amplitude. Following movements were stimulated by moving a target along a perimeter arc in the desired direction. The target was held approximately 75 cm. from the eyes.

eye in the sagittal plane. The superior rectus and inferior oblique are progressively inhibited. The lateral and medial rectus show no measurable change.

C. Adduction. Figure 3 is the multiple-channel electromyogram of a right eye moving to the left. The first recording is the result of a poor insertion in the right lateral rectus and should be disregarded. There is increasing activity of the right medial rectus

Fig. 3.—Right eye moving to left in horizontal plane. Right lateral rectus not recording, because of poor insertion. No noticeable change in right superior rectus and right inferior oblique.

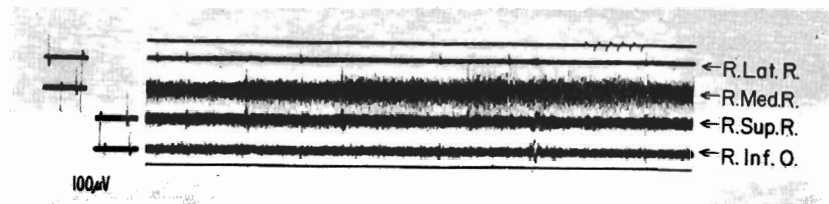


Fig. 4.—Adduction of right eye in horizontal plane. Note slight increased coactivity of vertical recti.

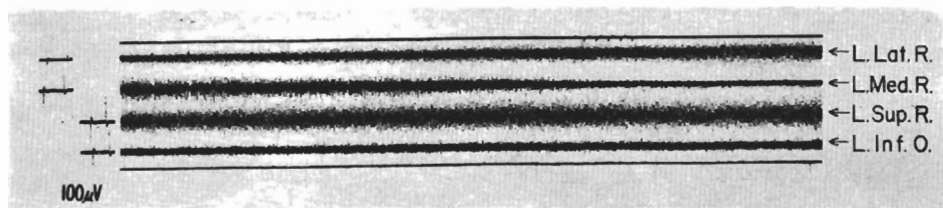
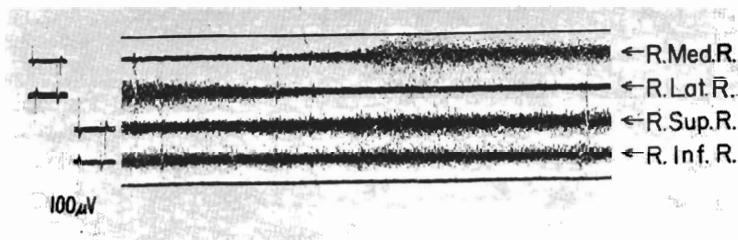


Fig. 5.—Abduction of left eye in horizontal plane. No apparent change in left superior rectus and left inferior oblique.

as the eye proceeds nasalward. The right superior rectus and the right inferior oblique show no noticeable change with adduction.

The absence of coactivity was a general finding. Occasionally the tracings did suggest possible coactivity. For example, in Figure 4 we see a slight increase in activity of the superior and inferior rectus muscles as the right eye is adducted. The right medial and lateral rectus muscles are reciprocally innervated as the right eye moves to the left.

*D. Abduction.* In Figure 5 the left eye is turning outward. The left lateral rectus and the left medial rectus are reciprocally innervated. The left superior rectus and the left inferior oblique show no apparent change in activity during this movement.

### Comment

It appears that there is little or no increased coactivity of auxiliary extraocular muscles in adduction, abduction, supra-adduction, and infraduction during slow, vertical, and horizontal following movements in planes through the primary position. This does not necessarily mean that they do not contribute to the movement. As indicated earlier,<sup>3,4</sup> the effect of muscle activity on eye movement depends upon the position of the eye at that moment. Hence, the primary position innervational tonus of the auxiliary

muscles, which does not apparently change during these movements, may indeed contribute to the movement after the eye has gone a certain distance. For example, in Figure 5 the left superior rectus, although showing no change, may be contributing to the abduction of the left eye after the left eye has gone outward more than 23 degrees, and the left lateral rectus is losing its abducting power. Also, the primary position tonus may be all that is necessary to steady the eye and prevent torsion during the movement. In other words, we can only deduce muscle contraction with certainty from the electrical activity of a muscle, but not necessarily the function of the muscle at that moment.

One can therefore say that normal muscle activity as found in the primary position is present in the auxiliary muscles during this movement but that systematic changes in coactivity do not generally occur. We are therefore in basic agreement with Breinin's conclusion regarding the same problem.<sup>9</sup> Adler<sup>10</sup> found slight increased electrical activity in the lateral rectus in straight up and down gaze of an eye, just as we found in the vertical recti (Fig. 4). Occasionally, one does find barely perceptible changes in the traces of the auxiliary muscles during such movements. These changes, when visible, have no systematic pattern and therefore

are not consistent with the cocontraction hypothesis, which would require systematic changes with a given direction of movement.

Generally speaking, we cannot detect the change in electrical activity corresponding to a slow movement of an eye of less than 8 degrees. This could limit our conclusions to the sensitivity of this system. However, since the changes that are occasionally found show no systematic pattern, there appears to be no such limitation on our conclusions.

### Summary

Multichannel electromyography on human extraocular muscles demonstrates little or no increased coactivity of auxiliary muscles during slow vertical and horizontal following movements in planes through the primary position.

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