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Electromyographic Study of Following Movements of the Eye Between Tertiary Positions

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In a previous paper,[1] coactivity of extraocular muscles was studied during slow following movements with utilization of multiple channel electromyography. After this, a study of coactivity during following movements of the eye between tertiary positions was attempted. The same technique, previously described,[2] was employed.

Cocontraction is defined as a simultaneous increased contraction of extraocular muscles which are normally antagonistic in their primary field of action. By movements between tertiary positions, we mean horizontal movements in upper and lower fields of gaze and vertical movements in right and left fields of gaze. We shall sometimes refer to the planes of such movements as tertiary planes.

The upper and lower fields of gaze were approximately 40 degrees above and below the horizontal. The right and left planes of gaze were approximately 50 degrees to either side of the primary position. Similarly, the amplitudes of the vertical movements were approximately 40 degrees above and below the horizontal, while the horizontal excursions were approximately 50 degrees to either side. The target consisted of a small light held at a distance of about 70 cm. from the eye. All electromyograms in this paper were filmed at a camera sweep speed of 30 in. per minute.

It became apparent early in this experiment that we could not look for coactivity in tertiary plane movements, because in each field of gaze one member of the pair of muscles to be observed for coactivity was largely inhibited and any small changes in its activity would not be visible on the tracing. However, these movements yielded other interesting information, and it is the purpose of this paper to report such findings.

A. Horizontal Movements in Upper Field of Gaze

Here it appears that the superior and inferior rectus muscles are more active in abduction, whereas the inferior oblique was more active in adduction. No insertions

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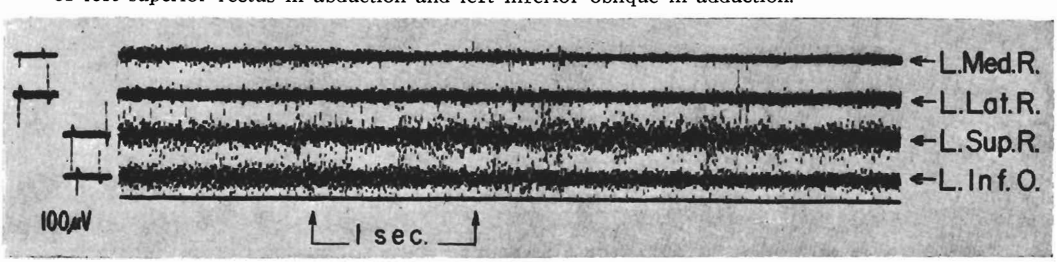
Fig. 1.—Left eye moving from up and right to up and left gaze. Note increased activity of left superior rectus in abduction and left inferior oblique in adduction.



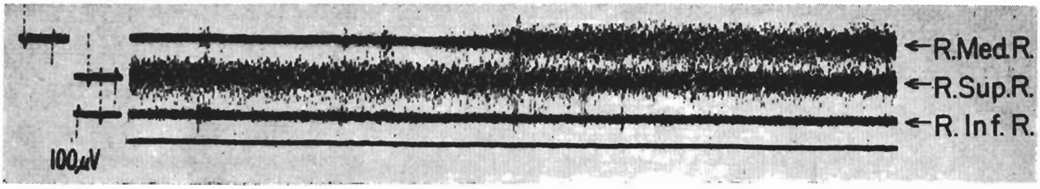


Fig. 2.—The right eye is moving from up and right to up and left gaze. Note greater right superior rectus activity in abducted position and no change in the inhibited right inferior rectus.

were made into the superior oblique through the intact conjunctiva, and, therefore, no recordings of this muscle will be shown.

In Figure 1 the left eye is moving from the up and right field of gaze to the up and left field of gaze. Note that as the eye undergoes this movement the left superior rectus increases in electrical activity, while the left inferior oblique decreases in activity. This finding of increased electrical activity of the vertical recti in abduction and the inferior oblique in adduction was very constant within and among subjects.

Again, in Figure 2, as the right eye moves from up and right position to up and left gaze, the right superior rectus shows greater electrical activity in the abducted position as compared with the adducted position. The right inferior rectus, inhibited in the upper field of gaze, shows no significant change in electrical activity.

B. Horizontal Movements in Lower Field of Gaze

Here again the vertical recti show greater activity in abduction and the inferior oblique is most active in adduction.

In Figure 3*A* the right eye is in the down and right position. In Figure 3*B*, taken a moment later, the same right eye has moved to the down and left position. Note the greater activity of the right inferior rectus in the abducted as compared with the adducted position. The superior rectus, inhibited in down gaze, shows no change, while the horizontal recti show the appropriate change of reciprocal innervation.

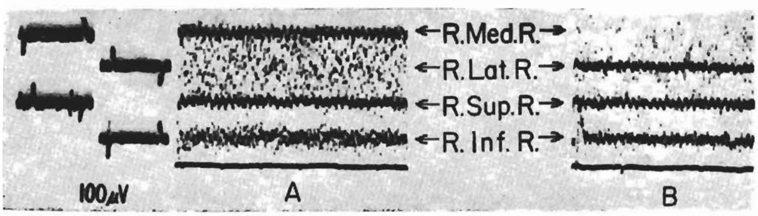


Fig. 3.—In *A* the right eye is in down and right gaze; in *B* the same eye, a moment later, in down and left gaze. Note greater right inferior rectus activity in abducted position and no change in the inhibited right superior rectus.

Figure 4 also demonstrates increasing activity of the right inferior rectus as the right eye moves from down and left gaze to down and right gaze. Again, there is no observable change in the inhibited superior

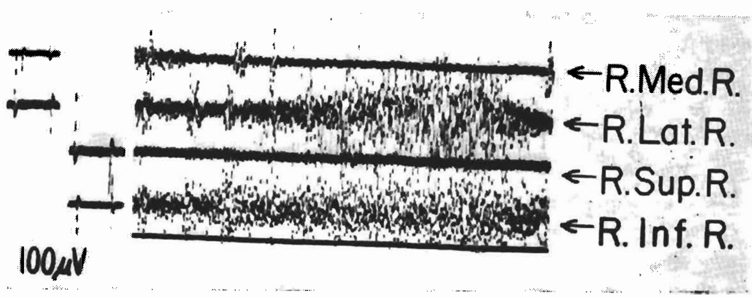


Fig. 4.—Right eye moving from down and left to down and right gaze. Note greater right inferior rectus activity in abduction and no change in the inhibited right superior rectus.

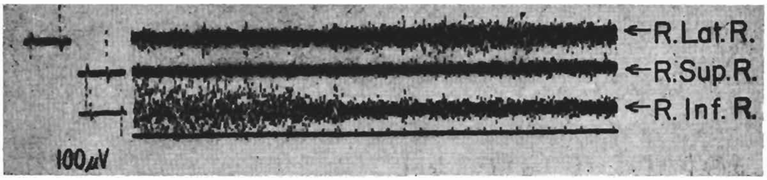


Fig. 5.—The right eye is moving from down and right to up and right gaze. Note increased right lateral rectus activity in the upper field of gaze.

rectus muscle, while the horizontal recti show the expected reciprocal innervation.

C. Vertical Movements in the Right Field of Gaze

In contrast to the findings above, the horizontal recti show great variability of activity from subject to subject in vertical movements in tertiary planes. For each individual subject, retest gave the same findings.

In Figure 5, the right lateral rectus shows greater activity in the up and right position as compared to the down and right position, whereas in Figure 6, the right lateral rectus is more active in down and right gaze (Fig. 6*A*) as compared with up and right gaze (Fig. 6*B*).

The medial rectus, too, shows this inconsistency. In Figure 7, the left medial rectus shows greater activity in down and right gaze as compared with up and right gaze, whereas in Figure 8, the left medial rectus shows greater activity in up and right gaze as compared with the down and right position. The inhibited left lateral rectus in both instances shows no change.

D. Vertical Movements in Left Field of Gaze

In this field of gaze, the medial and lateral rectus muscles continue to show no consistent pattern of activity in vertical movements.

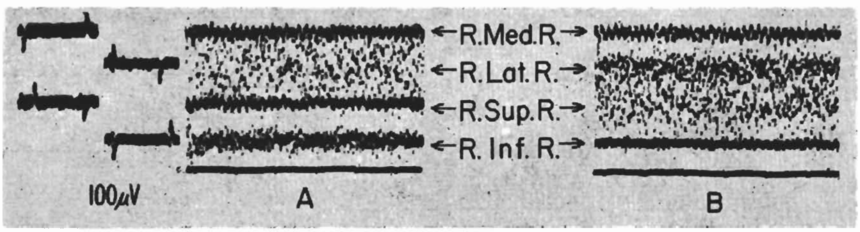
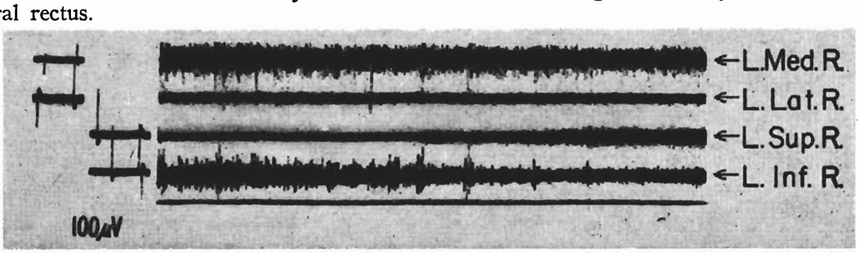


Fig. 6.—*A*, the right eye in down and right gaze; *B*, the same eye, a moment later, in up and right gaze. Note increased right lateral rectus activity in the lower field of gaze.

In Figure 9, the right medial rectus is more active in down and left gaze as compared with up and left gaze, whereas in Figure 10 the reverse is found. In Figure 9, the left lateral rectus is more active in down and left gaze as compared with up and left gaze, whereas in Figure 11 the reverse is noted.

In vertical movements both in right and left fields of gaze it was sometimes noted that the active horizontal muscles showed

Fig. 7.—The left eye is moving from down and right to up and right gaze. Note increased left medial rectus activity in lower field and no change in activity of inhibited left lateral rectus.



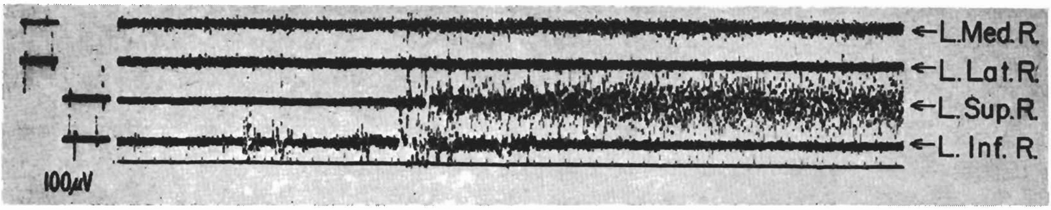


Fig. 8.—The left eye is moving from down and right to up and right gaze in another patient. Now left medial rectus activity is greater in upper field. Again there is no change in activity of the inhibited left lateral rectus.

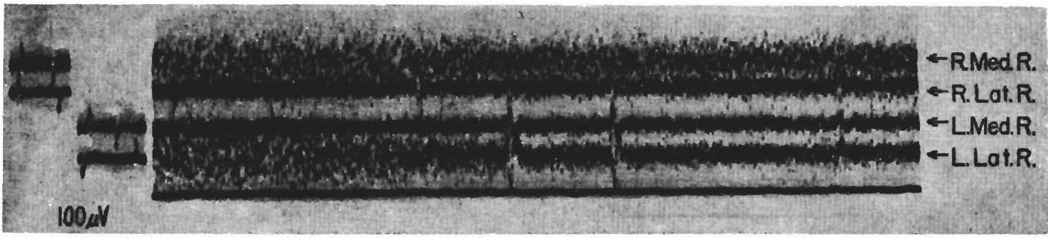


Fig. 9.—The right eye is moving from down and left gaze to up and left gaze. Note that the right medial rectus and left lateral rectus are more active in the lower field of gaze.

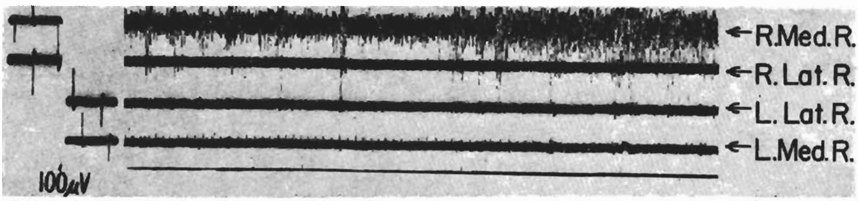


Fig. 10.—In another patient, the right eye is moving from down and left to up and left gaze. Now the right medial rectus is more active in the upper field of gaze, whereas the left lateral rectus shows no significant change.

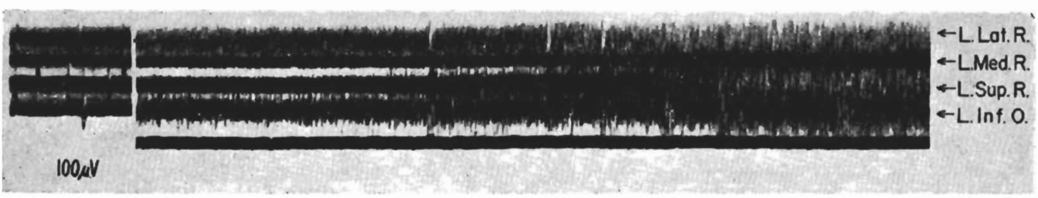
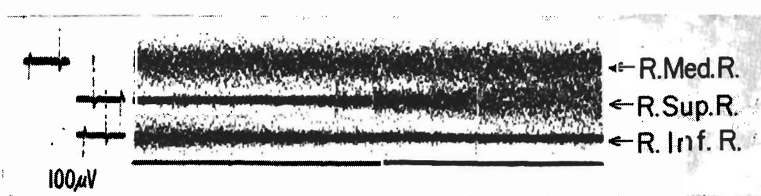


Fig. 11.—Left eye moving from down and left to up and left gaze. Now left lateral rectus is more active in upper field (compare with Figure 9).

Fig. 12.—The right eye is moving from down and left to up and left gaze. There is no significant change in right medial rectus activity.



no significant change in electrical activity. For example, in Figure 12, the right medial rectus muscle shows no significant change in activity as the right eye moves from down and left to up and left gaze.

Comment

The consistent findings of greater activity of the vertical recti in abduction and of the inferior oblique in adduction during following movements between tertiary positions is in agreement with similar findings by Breinin.[3] On the other hand, we have found no consistent variation in activity from subject to subject of the horizontal recti in vertical following movements between tertiary positions of the eye. Momosse[4] found no significant change in activity of vertical recti in horizontal movements 23 degrees above and below the horizontal and in the horizontal recti in vertical movements 23 degrees to the right and left of the vertical. Had he chosen his horizontal and vertical tertiary planes farther from the primary position, he probably would have obtained changes similar to ours and Breinin's.

We cannot, at this time, offer a satisfactory explanation relative to the constant increase in activity of the vertical recti in abduction and the inferior oblique in adduction in tertiary plane following movements. Whether this is due to anatomical, torsional, or other requirements is not clear at the moment. It is to be remembered that there is no significant systematic change in electrical activity of any of the extraocular muscles acting as auxiliary muscles during following movements in horizontal and vertical planes through the primary position.[1]

Neither can we explain the different alterations of various subjects in horizontal recti activity during vertical following movements between tertiary positions. The mechanism of peripheral proprioceptive feedback[5-7] offers an attractive field for speculation and future research.

Breinin[8] attempts to explain the A or V syndrome[9] on the basis of changes in activity of the horizontal recti during vertical movements. In a few of his cases of this syndrome, the horizontal recti exhibited no particular change in vertical gaze. Here, by exclusion, he ascribes the incomitance to the vertical muscles. Because of the normal variation in activity of the horizontal recti in tertiary plane movements, it appears misleading to draw conclusions regarding causation of the A or V syndrome without at least adequate sampling. Furthermore, the mere presence of increased activity of the muscles may only reflect the new position of the eye rather than tell us why the eye moved to this new position. For example, if the eye of an exophore is covered, that eye will deviate outward under cover and the electromyogram will show increased activity of the lateral rectus of that eye. This does not mean that an abnormally overactive lateral rectus muscle caused the exophoria. It simply means that the eyes are moved by eye muscles and that, in this case, the deviated eye was pulled outward by its lateral rectus muscle.

Conclusions

In horizontal following movements between tertiary positions the vertical recti are consistently more active in abduction than adduction, whereas the reverse is true for the inferior oblique. The horizontal recti manifest no consistent pattern of electrical alteration from subject to subject in vertical tertiary plane following movements. Possible changes in coactivity could not be successfully detected during following movements of the eye between tertiary positions of gaze because of the masking effect of reciprocal inhibition of one member of the normal agonist-antagonist pair.

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