ELECTROMYOGRAPHIC STUDIES ON RECOORDINATION OF LEG MOVEMENTS IN POLIOMYELITIS PATIENTS WITH TRANSPOSED TENDONS.

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Electromyographic Studies on Recoördination of Leg Movements in Poliomyelitis Patients With Transposed Tendons.*

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Man, in contrast to lower mammals,[1] can retime the action phase of a transposed muscle in accordance with its new function. Just how this occurs, is largely unknown. A systematic investigation of "recoördination," therefore, offers points of great theoretical and practical interest. A first report of our results is herewith presented.

Technic. The muscular action potentials were amplified in an ordinary vacuum tube amplifier set and recorded by an electromagnetically driven stylus writing on "Teledeltos" paper. Before entering the recorder, the amplified action currents passed through rectifying and integrating sets, partially summating and integrating individual spikes so as to give an estimate of the intensity of the contraction. Three identical channels were in operation, admitting independent simultaneous recording from three muscles. Provisions were made for the synchronization of these records with motion pictures. The electrodes consisted of copper mesh embedded in moist agar pads and strapped to the skin, cca 1 inch apart. Needle electrodes inserted through the skin did not prove significantly superior to surface leads. Elaborate precautions and checks were devised to guard against leakage of current from other than immediately subjacent muscles.

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1 Rat—R. W. Sperry, *J. Comp. Neur.*, 1940, **73**, 379. For full review of the problem, see P. Weiss, *Comp. Psychol. Monogr.*, 1941, **17**, No. 4.

Tests. For the sake of standardization, the tests were restricted to a single type of operation, namely, transposition of the tendon of the M. biceps femoris to the extensor side of the knee joint to substitute for the weakened or lost action of a paralyzed M. quadriceps. The action of the transplant was to be compared with its preoperative flexor and extensor relations. The muscles chosen to represent the knee extensor and flexor group were the residual M. rectus femoris and the inner hamstrings, respectively. The action phases of these muscles during a number of standardized test performances (simple voluntary movements on command, resisted and unresisted; from prone, supine, seated, standing position; stretch reflexes; walking; bicycling; stooping, etc) were determined in both normal and poliomyelitic (unoperated) individuals. With these data as background, the behavior of the transplanted M. biceps could be systematically followed.

Results. Twenty cases of biceps transplantation (18 poliomyelitis, 2 spastics) have thus far been explored. Six of them were available for study both before and after the operation, while the others were old cases operated on from 2-10 years previously. The following observations are condensed from cca. 2500 feet of records.

Pre-operative. The electromyogram has revealed appreciable residual activity in many paralyzed muscles rated as negative by palpation. Steady activity of the weak M. quadriceps during flexor as well as extensor phases seems to be characteristic of coördination in poliomyelitics (except in side-lying position), in contrast to normal and spastic individuals. The M. biceps operates in flexor phase only.

Postoperative. Records taken when the operated leg was removed from the cast for the first time, showed no activity of the transplant during the early efforts of the patient to move. Soon, however, either during the first or one of the succeeding sessions, the transplant began to come in, at first in flexor phase. After that, only surprisingly few trials were required to make the transplant suddenly contract in extensor phase, too. Visualization of the task to extend the leg seems to be the prime aid to the patient; actual visual control and proprioceptive cues seem to be less important during the early phase of recovery. The transplant continues for some time to act in both flexor and extensor phases, and there is no evidence of automatic resumption of reciprocal innervation. Association of the biceps with the extensors does not by itself produce dissociation from the flexors. Only after a further practice period of individually

FIGS. 1 AND 2.

Electromyograms of thigh muscles during voluntary extension (E) and flexion (F) of knee. In all records the tracings, read from top to bottom, represent (1) M. biceps femoris, (2) Inner hamstring muscles, (3) M. rectus femoris, (4) Time signal in seconds.

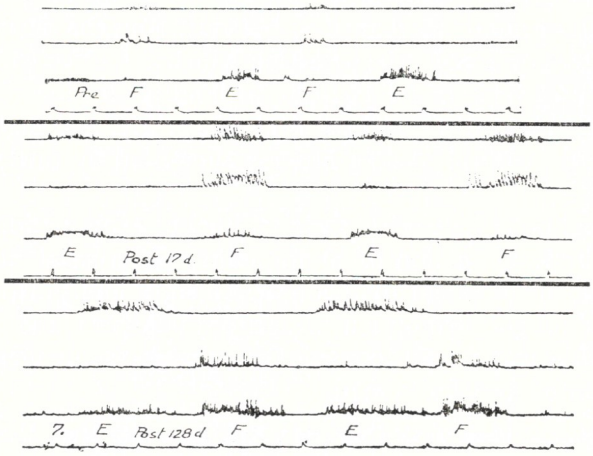

Fig. 1.

Three records taken from the same patient at different times. *Top:* Prior to the operation (side-lying position). Note Biceps action in flexor phase only. *Middle:* 17 days after tendon transposition. Note Biceps action in both flexor and extensor phases (F, E). *Bottom:* 128 days after the operation. Note absence of Biceps action during flexor phase.

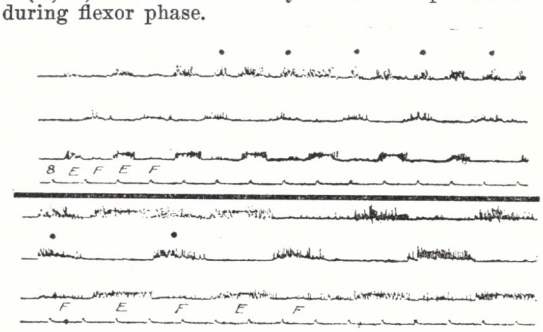

Fig. 2.

Relapse of transplanted Biceps into original flexor phase. *Top:* During fatigue towards end of prolonged test. Dots indicate occurrence of relapse. *Bottom:* Disorientation at beginning of performance. After two initial errors (marked by dots) transplant drops again its flexor association.

varying duration, does the transplant begin to be omitted during flexor actions.

Even then, however, temporary relapses into the old flexor association occur repeatedly, even years after the operation. These

relapses seem to be favored by fatigue, lack of concentration, automaticity of movement, etc. Their occurrence supports the view that the adjusted use of the transplant is not based on the substitution of a permanent extensor association for its former flexor association in the elementary motor mechanisms, but rather on the development in higher centers of a new type of action which can effectively override the innate coördinative associations without abolishing them. This corroborates the distinction between lower, rigid, and higher, plastic systems in the control of coördination suggested by earlier observations.[2]

These and numerous other facts still under examination (the fate of stretch reflexes; action of motor units; differential fatigue) exemplify the advancement of theoretical insight and practical knowledge concerning coördination which physiologists and orthopedic surgeons alike may expect to result from the electromyographic study of transplanted muscles in man.

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2 Weiss, P., and Ruch, T. C., PROC. SOC. EXP. BIOL. AND MED., 1936, **34**, 569.