AN EXPERIMENTAL STUDY OF THE FUNCTIONS OF THE LUMBRICAL MUSCLES IN THE HUMAN HAND

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INTRODUCTION

The many conflicting views expressed in the literature regarding the functions of the mm. lumbricales have been reviewed by Sunderland (1945), prior to giving his own observations as to their function based on evidence of nerve injuries. More recently, Braithwaite, Channell, Moore & Whillis (1948) have presented an entirely new concept of lumbrical muscle function founded on both experimental and clinical evidence. In order to assess the validity of the different functions attributed to the lumbrical muscles, their activity has been studied here by (1) electromyography, and (2) electrical stimulation. Normal subjects, not subjected to any form of anaesthesia, were used in all the experiments, a point considered essential both to preserve the normal functional activity of all muscles associated with the mm. lumbricales in digital movements, and to avoid certain of the pitfalls encountered by previous workers in this field.

ELECTROMYOGRAPHY

Muscle action potentials were obtained from concentric needle electrodes constructed from 40 s.w.g. enamelled copper wire (diameter 120 μ), cemented into a size 20 hypodermic needle. Photographic recordings were obtained using an a.c. coupled amplifier and a cathode-ray tube. Although all the lumbrical muscles were examined to exclude any individual variation, the second lumbrical muscle was chosen in most experiments for the following reasons:

(1) It is the easiest of the four muscles to contact with accuracy at a depth of 5–7 mm. The anatomical accuracy of position was initially tested in the cadaver, by inserting the needle and then checking the position of its point by dissection. So long as the position of the flexor tendons can be found by palmar observation or palpation, insertion of the needle into the muscle is quite a simple procedure.

(2) It is remote from both the thenar and the hypothenar muscle groups, so that electrical interference from these is rendered unlikely.

(3) It is separated from the mm. interossei by the transverse head of m. adductor pollicis. The superficial position of the needle in relation to this last muscle can be demonstrated by inserting it more deeply until electromyographic recordings are obtained during thumb adduction, using the same amplification as that required for lumbrical recordings. The needle is then withdrawn to the correct depth for the lumbrical muscle.

With the needle within the second lumbrical muscle, and using the necessary amplification for recording therefrom, no electrical spread was detectable from the transverse head of m. adductor pollicis or from the other thumb muscles when these were acting with maximal force (Fig. 1).* Therefore no electrical activity was expected to spread from the more deeply lying interosseous muscles. This expectation was confirmed by taking simultaneous recordings from the second lumbrical muscle and the second dorsal interosseous muscle, using identical electrodes for both. The degree of activity observed in various movements of the fingers showed markedly different results in the two muscles. For example, in full extension at the metacarpo

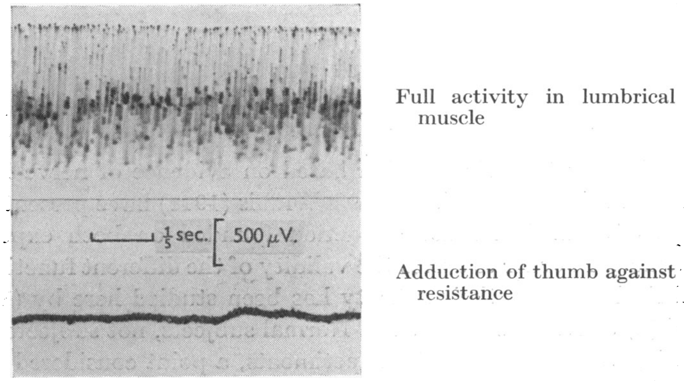


Fig. 1. Electrodes in second lumbrical muscle.

phalangeal and interphalangeal joints the lumbrical muscle showed a high level of electrical activity, whereas the interosseous muscle showed little or none. In full flexion at the same joints the lumbrical muscle showed no, but the interosseous muscle a marked, activity. It was found that in order to obtain the most satisfactory recordings the needle had to be placed within the lumbrical in as distal a position as possible. This procedure was rendered necessary by movements of the m. flexor digitorum profundus tendon which affect the position of the origin of the lumbrical muscle. There is, for instance, a tendency to bow-stringing on flexion which leads to variation in depth of the lumbrical in relation to the needle point if this be inserted too proximally; there is also considerable excursion of the needle point during flexion and extension, especially at the metacarpo-phalangeal joint.

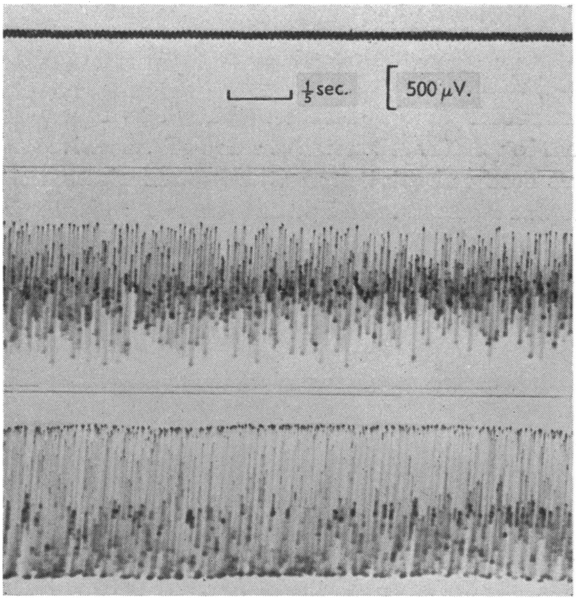
OBSERVATIONS

With the hand in the normal position of rest no action potentials were recorded from the lumbrical muscle.

Firm extension of the interphalangeal joints produced a high level of activity in the lumbrical muscle, irrespective of the position of the metacarpo-phalangeal joint (Fig. 2). This high level was maintained even in hyperextension at the metacarpo-phalangeal joint. One subject examined was able to hyperextend this joint actively to 45° with very little change in lumbrical activity throughout the whole range of movement (approximately 130°) at the metacarpo-phalangeal joint.

* The electrical recording during full activity in the lumbrical muscle in this figure, and also the third recording in Fig. 2, show overloading of the amplifier. This overloading was deliberate in order to show possible evidence of low levels of electrical activity in other movements.

Relaxation of interphalangeal extension, whatever the position of the metacarpo-phalangeal joint, produced an immediate reduction in the electrical activity in the lumbrical muscle. So marked was this that, even though no true digital flexion accompanied relaxation of extensor tension, the recorded action potentials were reduced almost to nil. Hence it was extremely difficult to assess variation of lumbrical action potentials in relation to the position of the metacarpo-phalangeal joint. Although subjects endeavoured to maintain a steady interphalangeal extensor tension throughout the whole range of movement at the metacarpo-phalangeal joint, results were rather variable, not only from subject to subject but also periodically in the same subject.



Hand relaxed in semi-flexion

Hand in firm extension at all joints

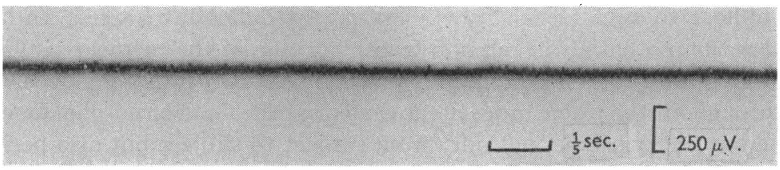
Firm flexion of metacarpo-phalangeal joints and extension of interphalangeal joints

Fig. 2. Electrodes in second lumbrical muscle.

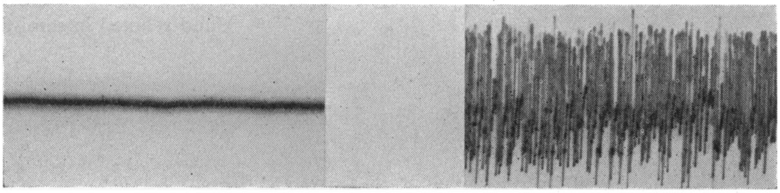
Flexion at the metacarpo-phalangeal joint with interphalangeal extension did appear to give a slightly higher level of lumbrical electrical activity than in metacarpo-phalangeal extension, but this observation must be treated with extreme caution in view of the difficulties stated above, and also in view of possible variations due to bow-stringing of the m. flexor profundus tendon. If flexion at the metacarpo-phalangeal joint is carried out with the interphalangeal joints extended, against a resistance applied at the finger tips, the degree of lumbrical activity is found to be reduced below the above level. Furthermore, activity in the lumbrical muscle during this movement could be completely abolished in subjects who relaxed their interphalangeal extension and allowed the digital position to be maintained by the flexion at the metacarpo-phalangeal joints and the counter-pressure at the finger tips.

Metacarpo-phalangeal flexion with interphalangeal flexion at no time produced any degree of electrical activity in the lumbrical muscle. This remained true even when such movement was made against maximal resistance.

Opposition of the medius digit to the thumb likewise produced no evidence of electrical activity in the lumbrical muscle, no matter what the intrinsic position of the thumb, so long as the interphalangeal joints of the medius were not actively



Forced opposition against thumb in extension
compared with



Muscle relaxed

Muscle fully active

Fig. 3. Second lumbrical muscle.

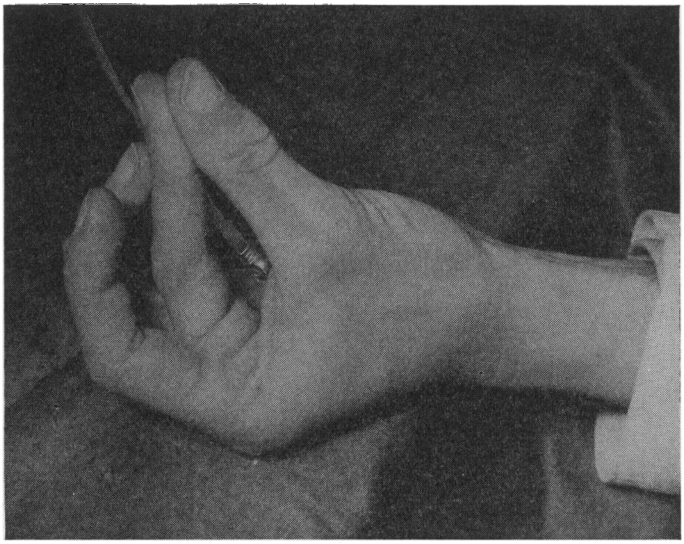


Fig. 4. The position of forced opposition against the thumb in extension in which the tracing in Fig. 3 was taken.

extended in the movement (Figs. 3, 4). If, however, active interphalangeal extension did occur in the finger during this movement, then electrical activity appeared in the muscle.

Radial deviation of the digit produced no electrical activity of the lumbrical muscle in any position of the metacarpo-phalangeal joint so long as no such activity was present before the initiation of this movement. (Radial deviation here includes that peculiar excursion of the proximal phalanx upon the curved metacarpal head which has been designated 'digital rotation' (Braithwaite *et al.* 1948).) Radial deviation carried out against resistance with the interphalangeal joints passively extended produced relatively little variation in the degree of lumbrical electrical response. In some subjects indeed a reduction of response was noted (Fig. 5).

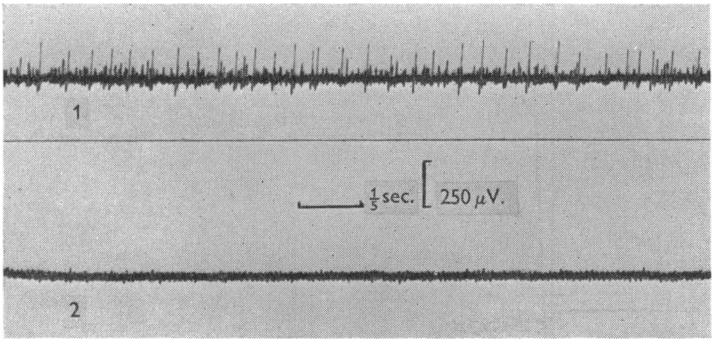


Fig. 5. Second lumbrical muscle: 1, relaxed in extension with ulnar deviation; 2, radial deviation against resistance.

The position of the wrist joint in no way affected the electrical activity of the lumbrical muscle engendered by interphalangeal joint extension.

STIMULATION

The lumbrical muscle was stimulated using for one electrode the core wire of the concentric needle electrode employed for the electromyographical study. This gave an effective stimulating area of the end of this wire of diameter 120 μ bevelled in one direction at approximately 45°. A large plate on the forearm was used for the other electrode, and was moved from place to place to exclude possible variation in stimulation effect. As would be expected from the small size of the intramuscular electrode, a high concentration of current was produced at this point: this concentration remained constant whatever the position of the plate-electrode. The voltages employed were those found to be sufficient for effecting lumbrical contraction yet low enough to obviate spread to neighbouring muscles. The stimulator employed gave a condenser shock discharge of $\frac{1}{2}$ msec. duration, at frequencies of between 50–100 per second, at an amplitude up to 60 V. d.c., from an internal impedance of about 600 Ω. The wave form was that shown in Fig. 6. Owing to the electronic circuit involved this wave did not show the classical sharp rise and exponential fall, though it did not differ greatly therefrom. The back edge of the pulse was more linear than exponential, due to inductance loading in the stimulator output circuit. This was also responsible for the small negative deflexion which followed the main pulse. The effective stimulation time was approximately $\frac{1}{3}$ msec. and the negative deflexion was shown to be too small to produce a stimulation.

Two stimulation currents were used, viz. (*a*) the maximum output of the stimulator, and (*b*) a lower current of about 30% of maximum output which was the minimum output capable of producing consistent stimulation of the muscle.

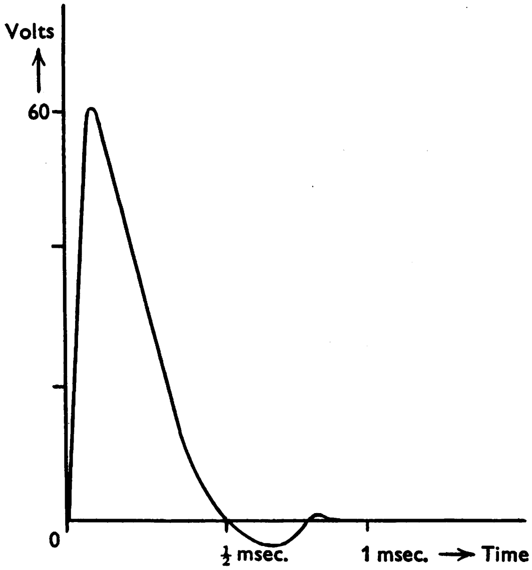


Fig. 6. Electrical wave-form given by the stimulator employed.

A high level of stimulation applied to the relaxed muscle produced firm extension at the interphalangeal joints, with flexion at the metacarpo-phalangeal joint to approximately 80° (Fig. 7). It was visually obvious that the initial lumbrical activity was always one of extension at the interphalangeal joints (no matter what the position of the metacarpo-phalangeal joint) followed by secondary flexion of the metacarpo-phalangeal joint.

A low stimulatory current, however, produced results which demonstrated the components of lumbrical function more simply. Such a current produced interphalangeal extension, the metacarpo-phalangeal joint retaining mainly its initial position. Full flexion at this latter joint occurred only if a higher current were passed. A certain small degree of metacarpo-phalangeal flexion invariably accompanied interphalangeal extension—relatively little if the metacarpo-phalangeal joint were initially extended, but rather more if it were partially flexed. The movement was in effect identical with the voluntary movement of interphalangeal extension in which it is extremely difficult to obviate a slight metacarpo-phalangeal flexor component. This flexor movement was, however, an essential part of the main movement of digital extension and differed from the pure flexion occurring after interphalangeal extension with higher currents.

No evidence of radial deviation was discernible.

Active control of the fingers against lumbrical stimulation was attempted by the subject in every case. It was found extremely difficult, or even impossible, to prevent extension of the interphalangeal joints if an adequate lumbrical stimulation current

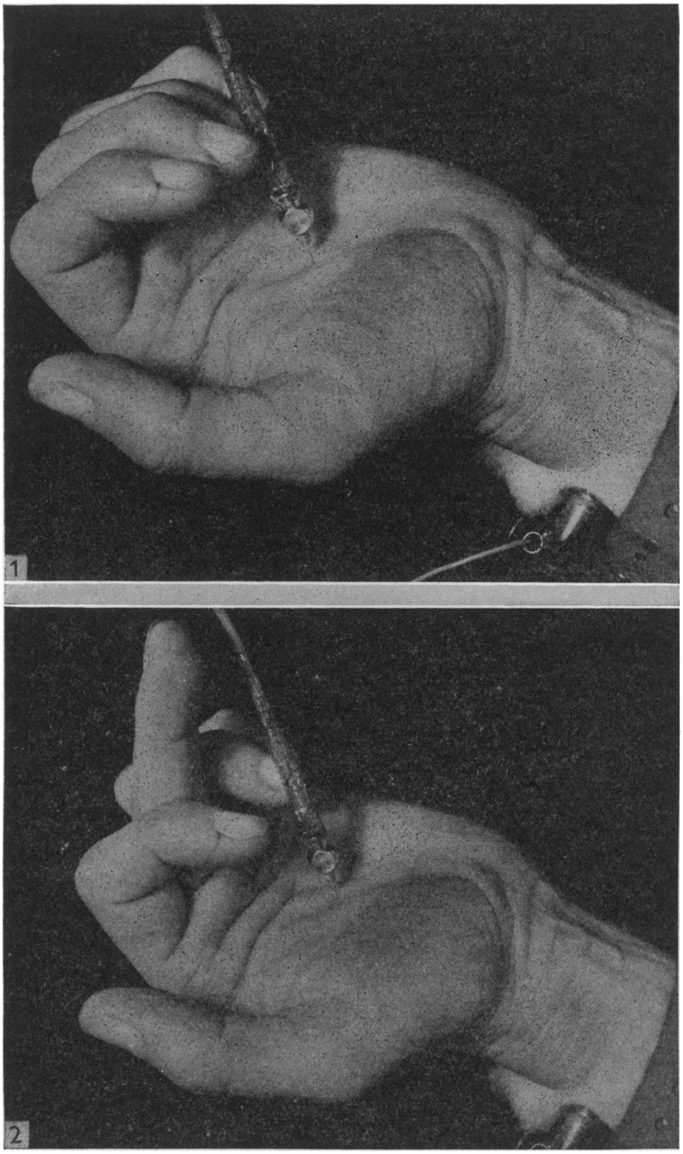


Fig. 7. Stimulation of the second lumbrical muscle: 1, hand relaxed; 2, muscle stimulated.

were used. When the interphalangeal joints were extended it was impossible to flex them against such stimulation. However, the effects of lumbrical stimulation upon the metacarpo-phalangeal joint differed. Stimulation led to metacarpo-phalangeal joint flexion if the interphalangeal joints were extended and the voltage was high enough, yet it was not difficult voluntarily to resist this movement. In fact the metacarpo-phalangeal joint could execute its full range of movement even when considerably higher currents were used than those necessary to render voluntary control of the interphalangeal joints impossible. Freedom of movement in a radial or ulnar direction, or of 'rotation', did not appear to be affected.

Sensations produced during lumbrical stimulation were experienced by the subjects and were found to be of a purely flexor-extensor character. Sensations of digital deviation or 'rotation' were entirely absent. On the other hand, stimulation of an interosseous muscle produced the remarkable sensation of complete loss of control due to deviation in the digit, a sensation absent in pure flexion-extension movements and entirely absent on lumbrical stimulation.

DISCUSSION

Interphalangeal extension. The evidence obtained from electromyographical investigation indicates that the lumbrical muscle acts primarily to produce extension of the interphalangeal joints, and this view is supported by the fact that similar activity is produced in the muscle on electrical stimulation. But it is apparent, both by observation and by palpation, that m. extensor digitorum communis is also contracting during active interphalangeal extension. Furthermore, Braithwaite *et al.* (1948) have shown that digital extension is an inefficient (but possible) movement in experimental paralysis of the long extensor. Therefore, the lumbrical muscle can be said to carry out this movement efficiently only in association with a normally acting m. extensor digitorum communis. Sunderland (1945) has suggested that an important aspect of lumbrical-interosseous extension at the interphalangeal joints is the prevention of hyperextension of the proximal phalanx by the m. extensor digitorum communis, and that this preventive action allows a more efficient pull to be transmitted to the dorsal expansion which then operates directly upon the interphalangeal joints. This view is herein supported in so far as the lumbrical muscles are concerned, on the evidence of the primary metacarpo-phalangeal flexor component occurring during digital extension after stimulation by even weak currents.

The prevention of hyperextension in digital extension cannot be the sole function of the lumbrical muscle, for such hypothesis fails to explain the relatively powerful extensor effect resulting from direct lumbrical stimulation, compared with the weaker secondary metacarpo-phalangeal flexor effect which follows the completion of extension. Furthermore, if the extensor effect were due solely to this preventive action, it would be reasonable to expect evidence of lumbrical muscle action in metacarpo-phalangeal flexion irrespective of the position of the interphalangeal joints, and such evidence has not been found in the present studies.

It appears, therefore, that the lumbrical muscle is an active extensor of the interphalangeal joints, and that its action is assisted very considerably by the m. extensor digitorum communis but only when the latter's hyperextensor effect upon the metacarpo-phalangeal joint is neutralized by the lumbrical or interosseous muscles.

Metacarpo-phalangeal flexion appears to be carried out by the lumbrical muscle only when the interphalangeal joints are extended. This view is strongly supported by the effect of lumbrical stimulation which results in flexion of the joint as a direct movement only subsequent to extension of the interphalangeal joints. The evidence of electromyography, though less convincing, does indicate the same conclusion, viz. that, although metacarpo-phalangeal flexion produces action potentials in the lumbricals only in active interphalangeal extension, the level of electrical activity appears to be higher in flexion than in extension of the metacarpo-phalangeal joint (Fig. 2). Although the value of this latter observation is not great it provides a certain supporting evidence.

Accessory movements. Present studies do not support the conclusions of Braithwaite *et al.* (1948) that the lumbrical muscles are active during digital opposition to the thumb or in digital radial deviation. The value of the lumbrical muscle as a radial deviator in the absence of interosseous muscle action cannot be assessed from these experiments.

SUMMARY

The actions of the lumbrical muscle have been studied experimentally by electromyography and by electrical stimulation.

The principal action of the muscle is that of an extensor of the interphalangeal joints, assuming that both the long muscles in union with which it operates maintain normal function. It is a weak flexor of the metacarpo-phalangeal joint, but effectively so only in interphalangeal extension. It appears to have no effect on 'rotation' or radial deviation of the finger and is not used in opposition of the finger to the thumb except in full and active extension of the digital interphalangeal joints.

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REFERENCES

Braithwaite, F., Channell, G. D., Moore, F. T. & Whillis, J. (1948). The applied anatomy of the lumbrical and interosseous muscles of the hand. *Guy's Hosp. Rep.* **97**, 185–195.

Sunderland, S. (1945). The actions of the extensor digitorum communis, interosseous and lumbrical muscles. *Amer. J. Anat.* **77**, 189–209.