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Sciatic nerve motor conduction velocity study[1]

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Electrophysiological investigation of human peripheral nerve has been extensively conducted over the past years. Motor conduction velocity determination has become a standard laboratory procedure, and its value in the diagnosis and localization of peripheral nerve lesions is well recognized. The method involves the application of an electrical stimulus on the skin overlying the nerve trunk with a surface electrode and the recording of muscle potential from a small muscle innervated by a terminal branch of the nerve. Deep-seated nerves are inaccessible to surface-stimulating electrodes. This procedure is, therefore, limited to a few superficially situated nerves. The latency and waveform of evoked muscle potential recorded from a big muscle vary with the nature and placement of recording electrodes, and their interpretation can at times be quite difficult. Certain methods (Arrigo, Cosi, and Savoldi, 1962; Gassel, 1963; Gassel and Diamantopoulos, 1964; Gassel and Trojaborg, 1964; Downie and Scott, 1964) to determine the conduction velocity of deep-seated nerves and those supplying big muscles have been introduced; however, they have not met with wide acceptance. The purpose of this study is therefore to establish a method for the determination of motor nerve conduction velocity of deep-seated nerve and to evaluate the problem of recording muscle potential from a group of big muscles.

Sciatic nerve is chosen as the subject for two reasons: 1 There is no vital structure nearby that may be damaged by a probing, stimulating electrode. 2 The motor conduction velocity of its terminal branches has been established by other workers (Hodes, Larrabee, and German, 1948; Carpendale, 1956; Henriksen, 1956; Thomas, Sears, and Gilliatt, 1959; Johnson and Olsen, 1960; Skillman, Johnson, Hamwi, and Driskill, 1961; Arrigo *et al.*, 1962; Mavor and Libman, 1962; Mayer, 1963; Angel and Alston, 1964; Gassel and Trojaborg, 1964; Mawdsley and Mayer, 1965; Mavor and Atcheson, 1966) whose studies can be used for comparison.

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MATERIAL AND METHODS

Thirty sciatic nerve studies were done on 19 individuals who had no history or physical findings of any neuromuscular disorders. They were divided into two equal groups. The arrangement of stimulating (S) and recording (R) electrode positions is illustrated in Figure 1. Only monopolar recordings were made. The active electrode (R_1) in the first group was inserted in or placed

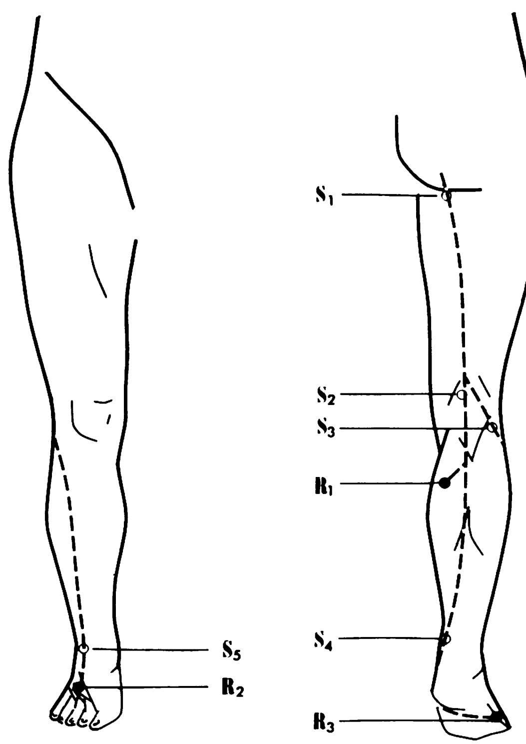

FIG. 1. *Positions of stimulating (S) and recording Electrodes.*

on the medial head of the gastrocnemius; both needle[1] and surface[2] electrodes were used. The reference electrode of the monopolar needle was grounded, while that of the surface electrode was placed on the bony prominence of the lateral malleolus. In the second group, simultaneous recordings of the extensor digitorum brevis (R_2) and abductor digit minimi (R_3) were made with surface electrodes, a common reference electrode being taped to the ball of the big toe. Ground was always placed between stimulating and recording electrodes. There were nine subjects in group 1, five males and four females; six of them had sciatic nerve studies done on both sides. Their ages were 21, 29, 36, 41, 42, 50, 50, 51, and 51. The subjects included in the second group were six males and four females, five of whom had studies done on both limbs. Their ages were 29, 30, 35, 36, 41, 44, 46, 53, 53, and 66.

A TECA TE2-7 two-channel electromyograph was used, the stimulus being a low impedance square wave pulse. The intensity required to produce supramaximal response ranged from 80 to 100 V, with a duration of 0·1 msec. Stimulation was made at multiple points (Fig. 1): proximal sciatic nerve at gluteal fold (S_1), distal sciatic nerve or medial popliteal nerve in popliteal fossa (S_2), posterior and anterior tibial nerves (S_4 and S_5) at the ankle. A needle electrode was employed as the stimulating cathode at S_1, the anode being an EKG rectangular plate 3 × 5 cm. placed on the flexor surface of the thigh near the gluteal fold. Stimulating electrodes for other points were bipolar surface electrodes with a diameter of 0·8 cm. and inter-electrode distance of 2 cm. Both electrodes were placed along the course of the nerve trunk with the cathode distally. The sciatic nerve was stimulated at two sites (S_1 and S_2) in the first group and at all five points (S_1-S_5) in the second group. The evoked muscle potentials were displayed on the oscilloscope and photographed with a Polaroid land camera. The conduction time and calculation of the conduction velocity were measured from the photographs.

TEMPERATURE CONTROL The E.M.G. laboratory is thermostatically controlled and a constant room temperature of 72° to 73°F. is maintained throughout the year. The feet of the subjects were washed with warm water first and kept warm with a blanket before and between studies.

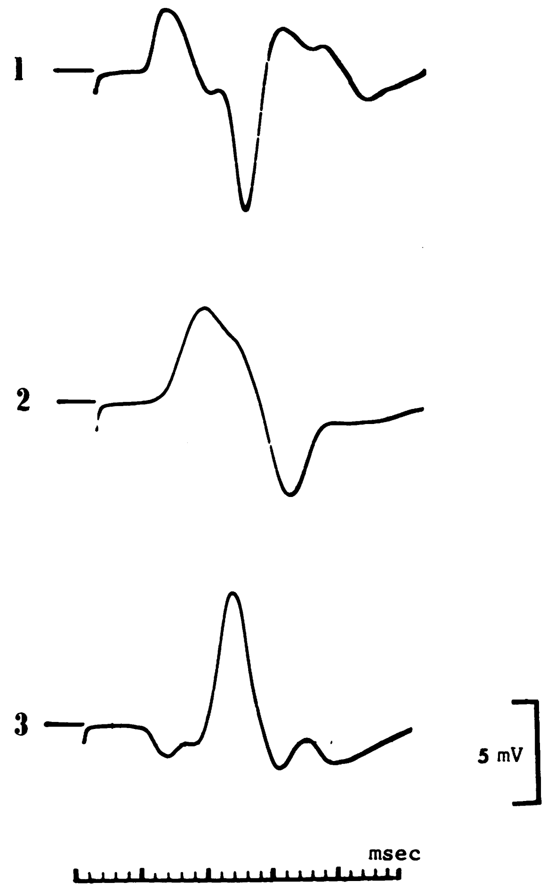

FIG. 2. *Muscle potentials recorded from the same position at the medial head of the gastrocnemius following stimulation of the medial popliteal nerve. The distance between stimulating and recording electrodes is kept constant (12 cm.): (1) when recorded with a needle electrode, stimulus at 100 V, 0·1 msec.; (2) when recorded with a surface electrode, stimulus at 80 V, 0·1 msec.; (3) with the same surface electrode when stimulus increased to 100 V, 0·1 msec. All negative deflections upward.*

RESULTS

GROUP 1: RECORDING ELECTRODE IN OR ON THE GASTROCNEMIUS When a stimulating electrode was held at a fixed position on the skin in the popliteal fossa overlying the medial popliteal nerve and the distance between stimulating and recording electrodes was kept constant, the latency and waveform of the muscle potential recorded from the gastrocnemius changed with the stimulus intensity and the kind of recording electrode used. These changes are illustrated in Figure 2. The muscle potential recorded with a needle electrode was generally polyphasic. If the needle was properly placed, a constant waveform with an initial negative wave could be obtained when the stimulus was kept supramaximal (Fig. 2, 1). The response recorded with surface electrodes was quite variable. A triphasic wave with an initial negative deflection (Fig. 2, 2) is obtained following stimulation of the medial popliteal nerve with a square wave pulse of V,80 0·1 msec. As the intensity is increased to

[1]TECA Teflon-coated monopolar E.M.G. electrode.
[2]Grass E1B, silver disc electrode.

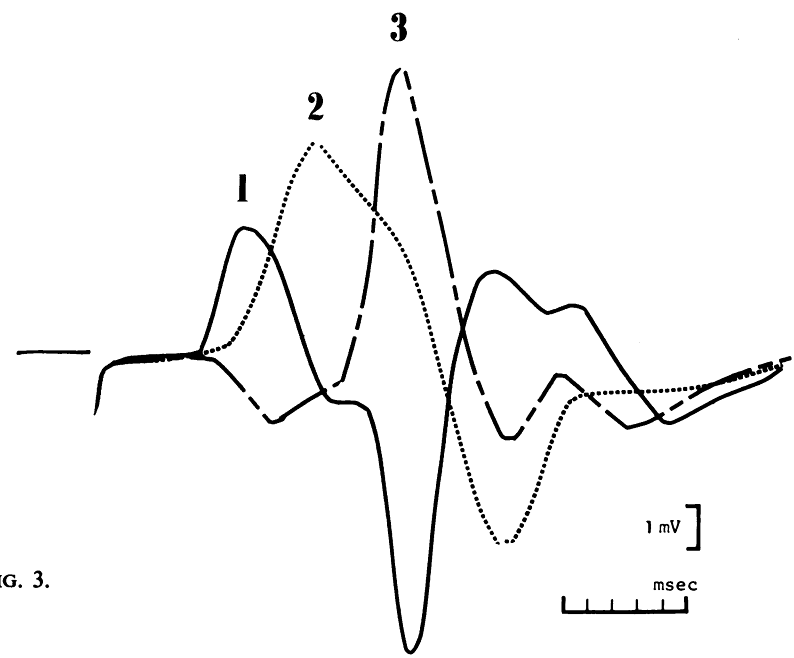

FIG. 3.

FIG. 3. *Superimposition of three responses in Fig. 2 by drawing.*

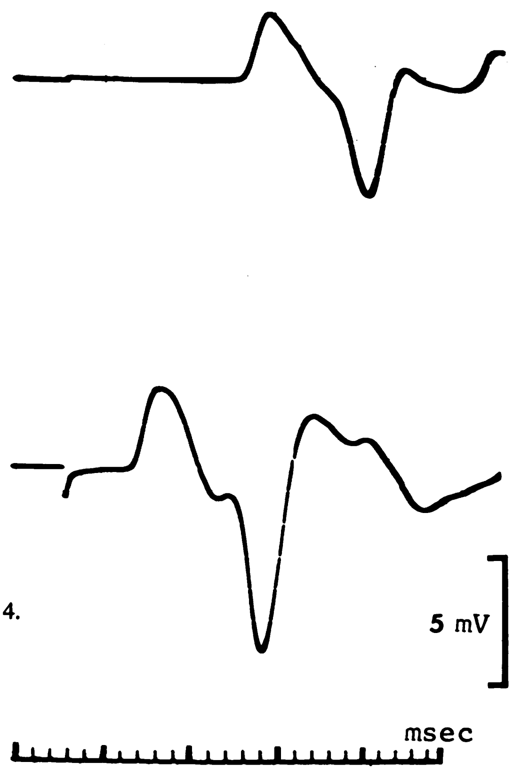

FIG. 4.

FIG. 4. *Muscle potentials recorded from the medial head of the gastrocnemius with needle electrode following stimulation of the sciatic nerve at 1, gluteal fold (S_1) and 2, popliteal fossa (S_2).*

100 V, 0·1 msec., an entirely different waveform appears (Fig. 2, 3). When all three potentials are traced on superimposition (Fig. 3), it becomes quite obvious that they are three different responses. Their latencies are different whether measured from the stimulus artefact to the take-off of first deflections, or to the peak of their first negative waves. Figure 4 shows the muscle potentials recorded from a monopolar needle electrode inserted into the medial head of the gastrocnemius following stimulation of the sciatic nerve at S_1 and S_2. These responses were typical of group 1: they were recorded with a needle electrode; similar waveforms were obtained when the sciatic nerve was stimulated at S_1 and S_2; their initial deflections were negative; they were responses to supramaximal stimulus. The time interval between stimulus artefact and the take-off of first negative deflection was taken as latency. The velocity was calculated accordingly. The distance between these two points of stimulation is 32·1 ± 3·8 cm.[1] (27-41 cm.). The conduction time of this segment is 10·6 ± 1·4 msec. (9·2-13 msec.). The conduction velocity of sciatic nerve is 53·8 ± 3·3 m./sec. (49·2-60·7 m./sec.) with the terminal latency of 4·7 ± 0·6 msec. (3·9-6·3 msec.) for a distance of 14·9 ± 1·8 cm. (12-17 cm.).

[1]The value of means and standard deviations were calculated from each individual item, *i.e.*, distance, conduction time, conduction velocity, etc.

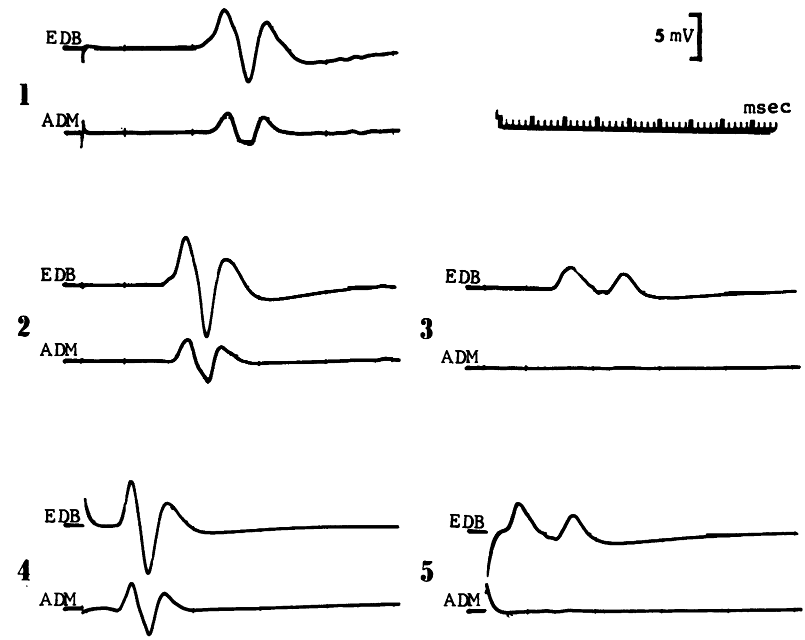

FIG. 5. *Simultaneous recordings from surface electrodes on the extensor digitorum brevis (EDB) and abductor digiti minimi (ADM) following stimulation of sciatic nerve and its branches at different points 1-5 corresponding to S_1-S_5 in Figure 1.*

GROUP 2: RECORDING ELECTRODES ON FOOT MUSCLES
Figure 5 shows the simultaneous recording of muscle potentials from electrodes on the extensor digitorum brevis (EDB) and abductor digiti minimi (ADM) following stimulation of the sciatic nerve and its branches at different points (Fig. 5, *1-5*) corresponding to stimulation at S_1-S. Muscle potential of the abductor digiti minimi was recordable only when the sciatic, medial popliteal or posterior tibial nerve was stimulated. The waveforms of the muscle potentials recorded following stimulation on the three sites were constant (Fig. 5, *1*ADM, *2*ADM, *4*ADM). On the contrary, some potentials were always recorded from the electrode on the extensor digitorum brevis on all five points of stimulation, though their wave-form varied. This variation can be observed in Figure 5. There is an inflection on the up-trough of the initial negative deflection of *1*EDB and *2*EDB; these two waveforms appear to be identical. The configurations of *3*EDB and *5*EDB are similar but different from those of *1*EDB and *2*EDB. No inflection on the negative deflection is seen on *4*EDB, which is distinct from *3*EDB and *5*EDB; *4*EDB is another kind of response by itself. This alteration of responses and their grouping into three types are fairly constant in this group except that *2*EDB may occasionally assume the appearance of *4*EDB instead of *1*EDB.

When the extensor digitorum brevis is paralyzed with xylocaine infiltration, response recorded from this muscle (Fig. 6, A-*2*EDB, B-*2*EDB) on stimulation of the anterior tibial nerve (S_5) disappears. However, the potential recorded from the same electrode (Fig. 6, A-*1*EDB, B-*1*EDB) on stimulation of the posterior tibial nerve (S_4) remains unchanged.

The conduction time of the sciatic nerve from the gluteal fold to the popliteal fossa could be determined by the difference of latencies between two muscle potentials of the abductor digiti minimi (Fig. 5, *1*ADM and *2*ADM) on stimulation of the buttock and behind the knee (S_1 and S_2). The latency at S_1 is 22·3 $\pm$ 1·8 msec (19·2-25 msec.) and at S_2, 15·7 $\pm$ 2·2 msec. (13·2-18 msec.). The velocity of the sciatic nerve as determined with this method is 51·3 $\pm$ 4·4 m./sec. (45·3-61·1 m./sec.) for a distance of 32·9 $\pm$ 2·4 cm. (26-36·5 cm.).

The conduction velocity of the medial popliteal nerve was calculated on the basis of latency difference between the two muscle potentials of the abductor digiti minimi (Fig. 5, *2*ADM and *4*ADM) following stimulation of the medial popliteal nerve (S_2) and the posterior tibial nerve (S_4). The velocity from knee to ankle is 43·4 $\pm$ 3·1 m./sec. (38·2-48·2 m./sec.) with the terminal latency of 6·3 $\pm$ 1·1 msec. (5-8 msec.) for a distance of 16·5 $\pm$ 2·5 cm. (12-21 cm.). The length of this segment is 40·9 $\pm$ 2·2 cm. (37·5-46·5 cm.).

The conduction velocity of the lateral popliteal nerve was determined in the same manner by the latency difference between the two muscle potentials of the extensor digitorum brevis (Fig. 5, *3*EDB and *5*EDB) on stimulation of the laterial popliteal nerve

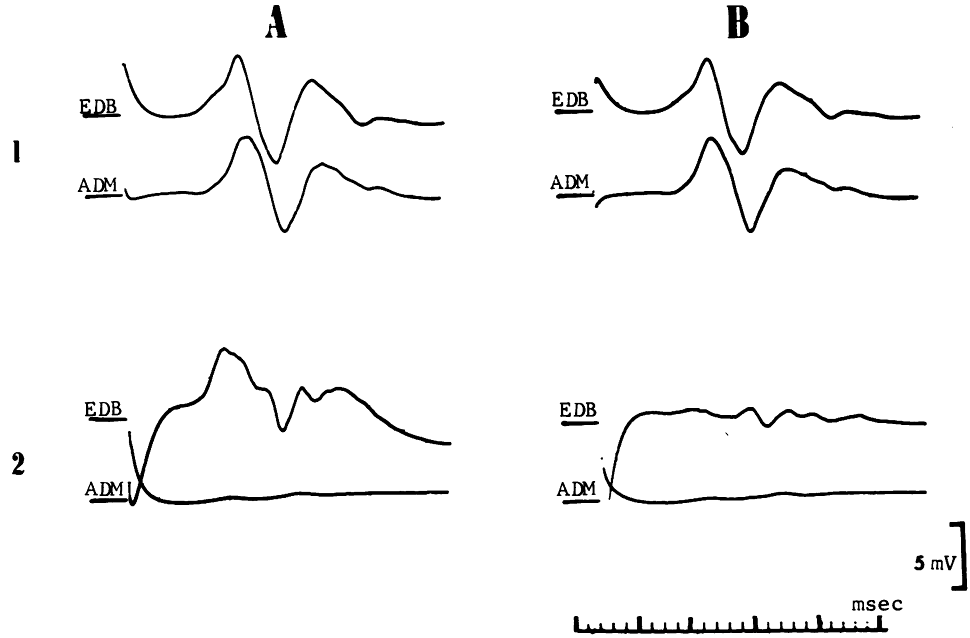

FIG. 6. *Simultaneous recordings from surface electrodes on extensor digitorum brevis (EDB) and abductor digiti minimi (ADM) following stimulation of posterior tibial nerve (1) and anterior tibial nerve (2) before (A) and after (B) xylocaine infiltration of extensor digitorum brevis.*

(S_3) and the anterior tibial nerve (S_5). The velocity is 45·5 ± 3·2 m./sec. (41-51·3 m./sec.) with the terminal latency of 4·9 ± 0·9 msec. (3·3-5·8 msec.) for a distance of 6·3 ± 1·6 cm. (4-9 cm.). The distance between knee and ankle (S_3 and S_5) is 37·5 ± 1·9 cm. (34·5-41 cm.).

GROUPS 1 AND 2 The mean age of the subjects in group 1 is 41·4 ± 11·7 (21-25 years) and that in group 2 is 41·3 ± 13·4 (29-66 years). Although they cover a wide range, there is no essential age difference in the two groups. Comparison of the sciatic nerve conduction velocity of these two groups does not show any statistical significance ($t = 1{\cdot}7$, $P>0{\cdot}1$). When all 30 studies of both groups are considered together, the sciatic nerve motor conduction velocity is 52·9 ± 3·9 m./sec. (45·3-61·1 m./sec.) for a distance of 32·5 ± 3·1 cm. (26-41 cm.).

DISCUSSION

THE STIMULATING ELECTRODE Both surface and needle electrodes have been employed by other authors (Arrigo *et al.*, 1962; Gassel and Trojaborg, 1964) to stimulate the sciatic nerve at the level of the gluteal fold. Our experience with surface electrodes was, however, very disappointing. The stimulus intensity was usually quite high (200-250 V, 0·5-1 msec.). It necessitated considerable probing and deep pressing with the electrode to locate and stimulate the nerve trunk. This invariably inflicted severe cutting pain and induced an area of ecchymosis and swelling. In spite of this we failed to stimulate the nerve successfully in most of our attempts. Needle electrodes, on the contrary, were found to inflict much less discomfort and induced no after-effect. There was no problem in locating and applying a supramaximal stimulus on the nerve trunk.

As long as the point of stimulation was kept constant, the latency of evoked muscle response remained unaltered when the size of the tip diameter of the surface stimulating electrodes was changed (Carpendale, 1956), or whether surface or needle stimulating electrodes were used (Mavor and Libman, 1962; Gassel, 1964). The choice of a stimulating electrode depended on the ease to stimulate the nerve trunk and the comfort of the subject. Our feeling was that needle electrodes should be employed to stimulate a deep-seated nerve, while surface electrodes would be sufficient for superficially located nerves.

THE RECORDING ELECTRODE AND MUSCLE POTENTIAL By recording action potential from a muscle, one actually registers the potential originating in a volume conductor through which the electrical current flows. When muscle fibre depolarizes, it forms a mobile, double dipole connected by negative poles. Negativity represents the site of depolarization. A recording electrode at the centre of depolarization will register a negative deflection, while at a distance a positive deflection.

To place a surface electrode on the gastrocnemius, one would record the potential changes of the entire calf muscles. If the gastrocnemius alone contracted following stimulation of the medial popliteal nerve, a potential with initial negative deflection would be recorded (Fig. 2, 2). With present techniques there is no way to control current density and to stimulate selectively a part of the nerve trunk. As the intensity of the stimulus was increased, nerve to the soleus would invariably be stimulated and the initial deflection would change and become positive (Fig. 2, 3).

Needle electrodes register only the potential change in a small area around the tip. They do not record potentials of other muscles. Positioning of the needle tip inside a muscle could be done with ease. When the needle tip is placed in the group of muscle fibres undergoing depolarization, the muscle potential should have an initial negative deflection and its latency would not be changed on supramaximal stimulation of its nerve supply (Fig. 2, 1).

It can be observed that the latency of these responses changes with the method of recording and the intensity of the stimulus, even though the distance between stimulating and recording electrodes is kept constant. For uniform recording and more accurate results, needle electrodes should be employed to record the latency of muscle potential from a group of big muscles for the determination of conduction time.

The muscle potential recorded from a surface electrode placed on the extensor digitorum brevis varies on stimulation of the sciatic nerve and its branches at different sites (Fig. 5, *1*EDB-*5*EDB). The potentials recorded (Fig. 5, *3*EDB and *5*EDB) on stimulation of the lateral popliteal and anterior tibial nerve were those of the extensor digitorum brevis because they disappeared on paralysis of this muscle, a finding previously reported by Gassel (1964) and presently confirmed in this study. The potential (Fig. 5, *4*EDB) recorded on stimulation of the posterior tibial nerve would have to be that of a muscle supplied by this nerve and situated close to the extensor digitorum brevis. This muscle would most probably be the third or fourth dorsal interosseous. Stimulation of the sciatic nerve invoked a superimposed response of these two potentials as evidence of the inflection at its first negative up-trough in Fig. 5, *1*EDB. If S_2 were at the distal segment of the sciatic nerve, the response (Fig. 5, *2*EDB), though not the latency, should be identical to *1*EDB. By the same token, if S_2 were at the medial popliteal nerve, no potential of the extensor digitorum brevis would be recorded and the response should be the same as *4*EDB. Since *1*EDB and *2*EDB were records of at least two superimposed muscle potentials of different origin, their latency should not be used for the determination of sciatic nerve conduction velocity.

THE CONDUCTION VELOCITY The sciatic nerve motor conduction velocity of 52·9 ± 3·9 m./sec. is similar to the findings of Arrigo *et al.* (1962) and Gassel (1964), though appreciably higher than that of Magladery and McDougal (1950). The means of motor conduction velocity for the medial popliteal nerve as reported by other authors range from 42·8-50·2 m./sec. (Hodes *et al.*, 1948; Henriksen, 1956; Thomas *et al.*, 1959; Johnson and Olsen, 1960; Skillman *et al.*, 1961; Arrigo *et al.*, 1962; Mayer, 1963; Angel and Alston, 1964; Gassel and Trojaberg, 1964; Mawdsley and Mayer, 1965; Mavor and Atcheson, 1966) and those for the lateral popliteal nerve, 46-50·9 m./sec. (Hodes *et al.*, 1948; Carpendale, 1956; Thomas *et al.*, 1959; Johnson and Olsen, 1960; Skillman *et al.*, 1961; Mavor and Libman, 1962; Mayer, 1963; Gassel and Trojaberg, 1964; Mawdsley and Mayer, 1965). The medial popliteal nerve motor conduction velocity of 43·4 ± 3·1 m./sec. and the lateral popliteal nerve motor conduction velocity of 45·5 ± 3·2 m./sec. are in agreement with the mean values of these authors.

The motor conduction velocity of the sciatic nerve is higher than that of its branches. The proximodistal decrease of conduction velocity has been noted by other authors (Arrigo *et al.*, 1962; Gassel and Trojaborg, 1964). A change in the motor nerve fibre diameter due to branching and tapering of the distal segment was considered as a possible reason for such variation.

SUMMARY

The sciatic nerve and its branches were stimulated at multiple points and action potentials were recorded from leg and foot muscles. Selection of electrodes for stimulation and recording was discussed. Muscle potentials recorded from different muscles with various techniques were analyzed.

Thirty studies of sciatic nerve motor conduction velocity were done and a value of 52·9 ± 3·9 m./sec. was obtained for a distance of 32·5 ± 3·1 cm. The motor conduction velocity of the medial popliteal

nerve from knee to ankle (40·9 ± 2·2 cm.) was 43·4 ± 3·1 msec. with the terminal latency of 6·3 ± 1·1 m./sec. for a distance of 16·5 ± 2·5 cm. The motor conduction velocity of the lateral popliteal nerve from knee to ankle (37·5 ± 1·9 cm.) was 45·5 ± 3·2 m./sec. with the terminal latency of 4·9 ± 0·9 msec. for a distance of 6·3 ± 1·6 cm.

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