Neurology Asia 2010; 15(1) : 39 – 54

Reference values for nerve function assessments among a study population in northern India - III: Sensory and motor nerve conduction.

[1]J McKnight, [2]PG Nicholls, [3]Das Loretta, [4]KV Desikan, [1]DNJ Lockwood, [5]EP Wilder-Smith, [6]WH van Brakel

[1]London School of Hygiene and Tropical Medicine, London, UK; [2]School of Health Sciences, University of Southampton, Southampton, UK; [3]The Leprosy Mission India, PO Naini, Allahabad, UP, India; [4]LEPRA India, Hyderabad, India; [5]Division of Neurology, National University Hospital, Singapore; [6]Royal Tropical Institute (KIT), Amsterdam, The Netherlands

Abstract

Objective: To identify reference values for normal sensory and motor nerve conduction in upper and lower limb peripheral nerves in a study population in India. The work was carried out in advance of the INFIR Cohort Study, a prospective study of individuals with newly diagnosed multibacillary MB leprosy, the objective being to identify early changes in nerve function predictive of new onset impairment and reactions. *Methods:* We assessed sensory nerve conduction in bilateral ulnar, median, radial cutaneous and sural nerves and motor nerve conduction in distal and proximal sites in bilateral ulnar, median and peroneal nerves among 315 healthy subjects. After adjustment for skin temperature and removal of outliers reference values were computed using regression analysis of log-transformed data. The analysis and resulting reference values were stratified by age and sex and based on the appropriate 5th or 95th percentiles. *Results:* Presented here are reference values for sensory nerve conduction velocity (SNCV), sensory nerve action potential (SNAP) amplitude and latency. Also for motor nerve conduction velocity (MNCV) and compound motor action potential (CMAP) amplitude at proximal sites and for amplitude and latency at distal sites. In each case percentiles are given by sex within four 10 year age bands. For males aged 55 years old, the reference value for ulnar SNCV was 43.6 m/sec and SNAP amplitude was 7.43 μV. Ulnar MNCV at the proximal site in the elbow was 50.8 m/sec and CMAP amplitude 7.25 mV and at distal sites in the wrist the amplitude was 7.14 mV and latency 3.1 msec. In the leprosy-affected cohort, the most common and therefore potentially the earliest impairment, is found in sensory nerve conduction amplitude of the sural nerve.

INTRODUCTION

Assessment of motor and sensory nerve conduction is a proven diagnostic tool in the testing of peripheral nerve damage.[1] Electrophysiological assessment of sensory nerve action potential (SNAP), compound motor action potential (CMAP) amplitudes, sensory nerve conduction velocity (SNCV) and motor nerve conduction velocity (MNCV) help to characterise and quantify the sensory and motor functions in the large myelinated fibres of peripheral nerves. Reference values are used to define the limits of normal function, with test values outside the range suggesting the presence of some form of neuropathy. Small fibre function is separately assessed with tests of pain, thermal perception, sweat or vasomotor function. Previous studies have reported differences in function related to ethnicity and demographic factors.[2-4]

The present paper is part of a series reporting normal reference values for a study population in northern India in advance of a prospective cohort study or individuals newly diagnosed with multibacillary leprosy. This is the first large study to make prospective assessments of vibration perception, warm and cold sensation and nerve conduction in order to identify the earliest available indicator of changes in nerve function related to leprosy reactions. Since loss of sensation in leprosy brings an increased risk of secondary impairments, identifying the early indicators of nerve involvement is a primary concern. While the TRIPOD study[5] suggested that prophylactic treatment of early involvement of large myelinated touch fibers detected by

Address correspondence to: Jason McKnight, London School of Hygiene and Tropical Medicine, Keppel St, London WC1E 7HT, UK. Email: jason.mcknight@lshtm.ac.uk

monofilament was not appropriate, alternative forms of nerve function assessment may detect other forms of nerve involvement, including those functions first affected.

The research was centred on the specialist leprosy referral centres in Naini and Faizabad, Uttar Pradesh, northern India, run by The Leprosy Mission International. Early findings of the Cohort Study have already been published.[6-10]

METHODS

Subject selection and sample size

Determination of the limits of normal function requires the collection and analysis of data from healthy subjects without a neurological condition drawn from a defined population group. In order to achieve a close match with individuals recruited to the cohort study we recruited subjects from among the healthy relatives accompanying individuals attending general and dermatology outpatient clinics at the two participating centres, applying inclusion and exclusion criteria as follows:

Inclusion criteria: Individuals were selected to obtain an equal number of male and female study subjects and by age group. In order to ensure the closest possible match with individuals recruited to the subsequent Cohort Study, equal numbers of subjects were included within four age bands up to 60 years, the maximum age for recruitment.

Exclusion criteria: Since the diagnosis of leprosy can only be made on clinical grounds all subjects were screened by an experienced leprologist leading to the exclusion of anyone exhibiting any clinical signs and symptoms of leprosy. Subjects with any known neurological disorder, previous contact with leprosy or a history of diabetes were also excluded. Individuals aged above 60 years or those less than 10 years were excluded. Nerve conduction testing was concurrent with the parallel studies focussing on thermal sensation and vibration perception. Some subjects were involved in more than one study.

To ensure adequate precision we studied 40 subjects within each of the four age groups for men and for women. The overall target for the number of normal subjects was therefore 320, equal numbers to be recruited in each centre.

Equipment and procedures

The equipment used was a Neurocare 2000 nerve conduction system supplied by BioTech (India). Data was saved in a standard Microsoft Access database. All testing was conducted in air-conditioned rooms with the temperature maintained in the range between 20 and 26˚C. Skin temperatures were recorded using a Testo Quicktemp electronic surface thermometer.

Protocol for testing and data recording

The nerves and test sites matched those used in the Cohort Study. Testing was done bilaterally on the cutaneous area of five nerves that are affected during leprosy neuropathy. For antidromic sensory conduction in the upper limbs, the ulnar and median nerves supplying digits 5 and 2 respectively, and the radial cutaneous nerve at the wrist, were studied. For the lower limb the sural nerve was studied behind the lateral malleolus. Action potentials were recorded at a standard distance of 14 cm in all nerves. Sensory testing produced assessments of SNCV and SNAP amplitude and latency for each nerve. Motor testing produced assessments of MNCV and CMAP amplitude and latency at proximal sites and CMAP amplitude and latency at distal sites for bilateral ulnar, median and peroneal nerves. All the neurophysiological tests were according to a standardised set-up with distances specified. Skin temperatures were measured electronically at wrist and ankle bilaterally. Further details of the study design are available in earlier publications.[11]

Nerve conduction testing was undertaken by the team of physiotherapists, who were also responsible for vibration perception and thermal threshold testing. After initial extensive on-site training given by a qualified neurophysiologist, four physiotherapists and a physio-technician in Naini and four physiotherapists in Faizabad completed inter-rater reliability testing. Within the centres each pairing was asked to complete up to 20 assessments of volunteer subjects. For this purpose we recruited subjects with a variety of neurological conditions that would ensure the assessors demonstrated reliability across the full range of nerve function. The results were analysed and demonstrated a good level of reliability.

Identification of outliers and calculation of reference values

A total of 315 subjects were assessed. Since the data collection procedure was fully automated data checking focussed on the accuracy of demographic data and the availability of data from all subjects assessed. Prior to analysis all assessments of latency and velocity were normalised for a

temperature of 33ºC using the standard formulae described by De Lisa *et al*.[12]

In view of age-related changes in parameters of nerve conduction we adopted a regression-based approach to identify outliers. For each assessment of latency, velocity and amplitude we used regression analysis of log-transformed data to compute age-adjusted estimates and identified observations with standardised residual in excess of 2.58 as outliers. These were then excluded from the remaining analysis. In view of differences between centres as well as between sexes the procedure was carried out separately within four groups defined by centre and sex. The first round of analyses proved effective in identifying the most extreme outliers. A judgement was then made as to whether the process should be repeated to remove further suspect assessments. The numbers of assessments excluded in this way are reported under the Results heading. In comparison to the procedure used in the earlier analyses, this procedure is more sensitive to differences between age and sex groups and results in a more conservative elimination of outliers.

Before computing reference values we used analysis of variance to assess differences between sexes, between age groups, between left and right sides and between centres. Left and right side assessments were then pooled, effectively doubling the sample size. We then used regression analysis of log transformed data on age within each sex and centre combination to compute the specific percentiles of normal limits.[13] Finally these were reverse-transformed to the original units of amplitude, latency or velocity as appropriate. Presented here are reference values based on estimates of the 95th percentiles for sensory and for motor nerve conduction latency and 5th percentiles for amplitude and velocity. These are based on a re-analysis of the data used in an earlier publication[6], the methods described here showing greater sensitivity to differences relating to sex and age.

Application of reference values

The reference values presented here were applied to identify impairment rates (percentages) among the 303 newly diagnosed cases of multibacillary leprosy recruited to the prospective INFIR Cohort Study. Other papers in the present series[14,15] describe reference values for vibration perception thresholds and for normal warm and cold sensation. The first of these provides more information on the cohort study.

Ethical Approval

Permission for all aspects of the INFIR study was obtained from the Indian Council of Medical Research through its Research Ethics Committee at the Central JALMA Institute for Leprosy in Agra gave ethical approval. Written consent was obtained from subjects enrolled in the Cohort Study. From individuals participating as subjects in the present study we obtained informed verbal consent, the great majority of those approached being willing to participate.

RESULTS

A total of 315 subjects were enrolled during the period from January 2000 up to July 2001. The distribution by age and sex is shown in Table 1. Mean age for men and women in Faizabad were 41.0 years (standard deviation 13.2) and 39.4 years (13.3) respectively and in Naini 39.7 years (13.5) and 37.9 years (13.6).

As a result of the two rounds of outlier elimination 0.95% of sensory assessments and 0.77% of motor assessments were excluded.

The four sections of Table 2 present summary statistics for left and right side assessments by centre, sex and age group for sensory nerve conduction velocity and amplitude, for proximal motor nerve conduction velocity and amplitude and for distal motor nerve conduction latency and amplitude. To assess the statistical significance of differences in assessments in each nerve relating to sex, age group and side we used analysis of variance of log-transformed data with age as a covariate. In the analyses of sensory assessments, there was a statistically significant age effect in latency, amplitude and velocity for sural and radial cutaneous nerves (all $p<0.01$ or higher levels of significance). Age also showed a statistically significant association with median and ulnar SNAP amplitude ($p<0.001$ in each case), but not with latency or velocity in these nerves. Statistically significant sex effects were found in all analyses relating to latency and velocity ($p<0.05$ or higher levels of significance) but in none of those relating to amplitude. The importance of these differences is reflected in the charts of Figure 1. No differences relating to side reached statistical significance. Including centre in the analysis did not change these findings, however, between centre differences reached statistical significance in all latency and velocity assessments and in amplitude assessments only for the sural nerve.

With the exception of ulnar CMAP distal

Table 1: Age and sex distribution plus row and column percentages for subjects assessed in two centres

Faizabad
Age groups (years)

Sex	⩽30 yrs	31-40 yrs	41-50 yrs	51-60 yrs	Total
Female	21 26.3, 52.5	20 25.0, 50.0	21 26.3, 52.5	18 22.5, 47.4	80 50.6
Male	19 24.4, 47.5	20 25.6, 50.0	19 24.4, 47.5	20 25.6, 52.6	78 49.4
Total	40 25.3	40 25.3	40 25.3	38 24.1	158

Naini
Age groups (years)

Sex	⩽30 yrs	31-40 yrs	41-50 yrs	51-60 yrs	Total
Female	24 30.8, 54.6	20 25.6, 51.3	17 21.8, 47.2	17 21.8, 44.7	78 49.7
Male	20 25.3, 45.5	21 24.1, 48.7	22 24.1, 52.8	20 26.6, 55.3	84 50.3
Total	44 28.0	39 24.8	36 22.9	38 24.3	157

latency, proximal and distal assessments in all three motor nerves showed a statistically significant age-related trend ($p<0.05$ or less). For the ulnar nerve, there were statistically significant age and sex interactions for MNCV and CMAP latency. There was also a statistically significant sex effect for median and peroneal CMAP proximal latency ($p<0.01$ and $p<0.05$ respectively). There were no statistically significant differences between left and right sides. Including a comparison between centres did not change these findings. In all analyses differences between centres were statistically significant ($p<0.01$ or less), the only exception being in CMAP proximal latency and CMAP distal amplitude for the median nerve.

For the remaining analysis we proceeded with calculation of thresholds based on pooled left and right side assessments. The resulting thresholds based on the 95th percentile are presented in Table 3, broken down by sex and four ten year age bands by centre and for combined centres.

The association with age, sex and centre is evident in the trends in reference values presented in Table 3. This is reinforced in Figure 1, which presents scatter plots for sensory and motor nerve conduction assessments for the ulnar nerve overwritten with the 95th percentiles based on data from combined centres plus a shaded area illustrating the distance between centre-specific thresholds.

Applying the thresholds based on centre, sex and age-specific 95th percentiles to assessments of the leprosy-affected cohort at time of diagnosis we computed impairment rates in all nerves (Table 4). These draw attention to the high rates of impairment found in the cohort and go far beyond the impaired rates identified by monofilament testing.[7]

The scatter plots for the ulnar nerve presented in Figure 2 further illustrate the extent of impaired function found in the leprosy cohort. In these charts a default extreme value was substituted for nerves found to be non-conducting.

Table 2A: N, mean, standard deviation and median for sensory nerve conduction velocity by nerve, centre, sex, age group and side

Age Group	Side	Ulnar	Median	Radial Cutaneous	Sural
		Sensory nerve conduction velocity in m/sec for male subjects by age group in Faizabad			
≤30 yrs	**Right**	19, 59.4 (7.6), 59.0	19, 54.9 (7.0), 54.7	18, 63.7 (8.6), 63.5	18, 56.3 (6.9), 57.1
	Left	19, 57.5 (6.9), 58.5	19, 54.9 (6.6), 54.5	18, 63.3 (7.7), 65.4	18, 56.2 (7.6), 59.2
31-40 yrs	**Right**	19, 58.8 (5.4), 59.1	20, 56.2 (7.3), 56.8	19, 66.8 (7.4), 68.6	18, 58.8 (5.7), 60.0
	Left	20, 57.3 (6.7), 58.0	20, 57.0 (5.8), 58.6	20, 64.9 (7.6), 67.5	20, 60.0 (6.8), 61.5
41-50 yrs	**Right**	17, 58.0 (6.2), 57.1	17, 56.7 (4.9), 56.3	17, 67.4 (7.3), 66.7	16, 61.2 (7.0), 63.4
	Left	17, 59.0 (6.3), 60.0	16, 58.1 (5.0), 57.9	17, 65.3 (6.3), 66.3	15, 60.2 (7.9), 58.5
51-60 yrs	**Right**	20, 56.0 (6.9), 55.1	20, 55.5, (8.0), 56.2	20, 64.6 (6.9), 63.8	18, 60.5 (7.3), 58.7
	Left	20, 57.2 (6.0), 55.6	19, 57.5 (4.5), 56.7	20, 65.6 (5.3), 66.5	18, 60.3 (6.4), 59.3
		Sensory nerve conduction velocity in m/sec for female subjects by age group in Faizabad			
≤30 yrs	**Right**	21, 60.3 (7.0), 61.5	21, 59.5 (7.5), 61.5	21, 65.8 (8.4), 66.7	21, 57.7 (6.3), 58.5
	Left	20, 59.8 (5.3), 59.8	21, 60.5 (7.7), 62.3	21, 65.5 (8.6), 67.5	21, 58.5 (6.5), 57.5
31-40 yrs	**Right**	19, 62.7 (5.4), 63.1	20, 61.6 (6.2), 60.8	19, 72.1 (5.9), 71.9	17, 62.7 (4.6), 62.8
	Left	20, 62.4 (5.7), 62.8	20, 63.9 (6.4), 64.1	20, 71.4 (6.5), 71.7	16, 64.7 (4.3), 65.4
41-50 yrs	**Right**	21, 60.0 (7.8), 60.0	21, 58.7 (7.9), 57.6	21, 68.7 (7.7), 68.6	21, 62.1 (4.7), 61.5
	Left	20, 62.5 (6.5), 63.1	21, 60.4 (8.6), 61.3	21, 69.1 (7.7), 70.5	21, 62.8 (6.5), 62.2
51-60 yrs	**Right**	18, 57.7 (6.2), 58.8	18, 55.8 (8.6), 55.8	17, 66.0 (7.7), 66.7	16, 62.5 (5.3), 64.0
	Left	18, 59.4 (6.3), 58.8	18, 55.8 (9.6), 56.5	18, 66.6 (7.5), 66.9	15, 62.0 (7.1), 63.6
		Sensory nerve conduction velocity in m/sec for male subjects by age group in Naini			
≤30 yrs	**Right**	20, 49.7 (5.4), 49.4	20, 50.4 (5.6), 51.4	20, 53.0 (5.2), 51.9	19, 45.1 (4.4), 45.3
	Left	20, 49.2 (5.7), 49.1	20, 49.2 (5.9), 47.8	19, 54.5 (7.1), 52.2	19, 46.8 (5.7), 45.7
31-40 yrs	**Right**	19, 55.1 (8.1), 55.4	19, 55.0 (7.2), 55.1	19, 57.8 (5.2), 57.1	19, 48.9 (4.8), 49.2
	Left	19, 53.4 (6.5), 52.6	19, 54.0 (6.7), 53.9	17, 58.6 (7.4), 58.1	19, 48.4 (4.7), 46.8
41-50 yrs	**Right**	18, 51.9 (6.3), 50.7	18, 53.1 (7.1), 51.3	18, 59.1 (6.9), 55.7	18, 48.9 (5.9), 47.7
	Left	18, 50.9 (6.3), 50.5	18, 52.1 (5.8), 52.8	17, 59.3 (7.9), 57.6	18, 50.2 (7.1), 50.1
51-60 yrs	**Right**	21, 54.6 (9.4), 54.7	21, 54.1 (6.6), 55.5	19, 59.7 (7.1), 60.8	20, 50.1 (4.9), 49.4
	Left	21, 52.2 (7.8), 52.3	21, 52.1 (5.2), 53.2	21, 57.6 (6.0), 58.3	21, 50.0 (5.4), 49.0
		Sensory nerve conduction velocity in m/sec for female subjects by age group in Naini			
≤30 yrs	**Right**	24, 56.5 (7.7), 57.0	23, 56.9 (6.0), 56.8	24, 57.9 (5.8), 57.9	24, 50.9 (6.5), 50.2
	Left	24, 53.9 (6.8), 53.1	24, 53.7 (5.7), 53.5	24, 56.8 (6.0), 56.0	23, 50.1 (5.2), 49.6
31-40 yrs	**Right**	20, 56.7 (5.9), 55.3	19, 55.1 (6.3), 57.4	20, 58.7 (5.6), 59.9	19, 53.7 (7.0), 53.3
	Left	19, 54.1 (5.7), 53.3	18, 54.9 (6.7), 54.3	19, 57.9 (6.1), 57.4	19, 51.9 (5.8), 51.8
41-50 yrs	**Right**	17, 54.9 (9.8), 54.4	17, 55.2 (8.2), 54.5	17, 58.4 (8.6), 59.8	17, 51.4 (7.5), 53.2
	Left	17, 55.2 (8.1), 58.7	17, 54.7 (7.2), 57.2	17, 57.3 (9.0), 57.5	17, 50.0 (6.7), 51.5
51-60 yrs	**Right**	15, 56.2 (7.7), 57.3	17, 56.0 (8.1), 58.0	17, 59.6 (7.8), 59.3	17, 53.2 (3.7), 53.3
	Left	17. 54.7 (7.1), 55.0	17, 53.3 (5.8), 51.8	17, 58.2 (7.5), 57.9	17, 52.3 (5.1), 51.8

Table 2B. N, mean, standard deviation and median for SNAP amplitude in μV by nerve, centre, sex, age group and side.

Age Group	Side	Ulnar	Median	Radial Cutaneous	Sural
		SNAP amplitude in μV for male subjects by age group in Faizabad			
⩽30 yrs	**Right**	19, 32.3 (18.5), 30.1	19, 47.7 (20.8), 39.4	18, 27.8 (9.4), 24.8	18, 29.7 (10.8), 27.4
	Left	19, 33.8 (16.0), 33.6	19, 45.3 (19.0), 42.0	18, 31.8 (8.7), 31.0	18, 27.9 (11.0), 28.4
31-40 yrs	**Right**	19, 33.0 (13.3), 31.0	20, 44.0 (15.8), 43.4	19, 28.0 (11.4), 24.8	18, 29.8 (16.0), 26.3
	Left	20, 32.4 (13.2), 30.7	20, 48.6 (15.6), 52.8	20, 31.2 (10.4), 33.0	20, 29.0 (15.3), 24.9
41-50 yrs	**Right**	17, 25.0 (10.4), 25.0	17, 43.8 (16.7), 43.0	17, 26.2 (8.8), 24.6	16, 23.3 (10.8), 20.9
	Left	17, 29.3 (12.4), 29.5	16, 45.2 (19.4), 44.3	17, 28.7 (8.9), 27.0	15, 21.6 (12.3), 18.2
51-60 yrs	**Right**	20, 23.6 (11.0), 24.0	20, 33.9 (14.3), 34.4	20, 21.4 (6.2), 20.0	18, 17.4 (5.5), 17.0
	Left	20, 23.7 (15.0), 20.2	19, 36.3 (13.5), 37.0	20, 23.6 (6.5), 23.2	18, 18.7 (5.5), 19.0
		SNAP amplitude in μV for female subjects by age group in Faizabad			
⩽30 yrs	**Right**	21, 33.2 (17.7), 29.8	21, 43.2 (19.3), 38.2	21, 29.6 (11.5), 26.2	21, 31.8 (12.1), 32.6
	Left	20, 36.8 (22.6), 30.8	21, 51.2 (27.0), 49.0	21, 31.3 (10.2), 28.5	21, 32.4 (14.5), 33.3
31-40 yrs	**Right**	19, 37.1 (17.0), 36.4	20, 57.5 (18.3), 58.6	19, 30.9 (8.8), 30.3	17, 21.3 (8.9), 20.6
	Left	20, 39.2 (20.7), 33.1	20, 62.2 (21.2), 64.4	20, 32.0 (9.5), 31.0	16, 22.8 (16.5), 19.3
41-50 yrs	**Right**	21, 33.5 (16.0), 32.8	21, 42.6 (15.0), 42.7	21, 31.8 (10.1), 29.2	21, 24.5 (9.7), 19.8
	Left	20, 42.1 (24.1), 35.9	21, 50.3 (24.7), 37.1	21, 33.2 (9.2), 34.1	21, 25.3 (10.9), 21.5
51-60 yrs	**Right**	18, 25.9 (13.2), 24.0	18, 34.2 (18.4), 27.9	17, 30.7 (8.9), 30.5	16, 20.0 (9.4), 18.5
	Left	18, 30.7 (23.0), 25.0	18, 38.8 (21.1), 41.0	18, 30.6 (14.5), 32.5	15, 17.6 (9.3), 19.1
		SNAP amplitude in μV for male subjects by age group in Naini			
⩽30 yrs	**Right**	20, 36.8 (19.7), 32.0	20, 42.9 (15.7), 44.0	20, 27.8 (9.3), 26.5	19, 21.6 (8.5), 23.9
	Left	20, 40.9 (18.6), 35.4	20, 46.3 (18.0), 47.4	19, 29.9 (10.5), 27.6	19, 22.9 (7.6), 22.8
31-40 yrs	**Right**	19, 29.0 (11.7), 27.2	19, 34.2 (17.5), 33.4	19, 25.9 (9.6), 24.7	19, 18.9 (8.9), 18.3
	Left	19, 34.2 (14.9), 30.2	19, 39.7 (22.6), 38.5	17, 32.2 (15.9), 28.7	19, 20.3 (10.5), 17.4
41-50 yrs	**Right**	18, 26.0 (15.3), 22.0	18, 29.6 (16.3), 27.0	18, 30.4 (8.8), 29.0	18, 19.2 (8.6), 17.3
	Left	18, 26.8 (12.8), 22.6	18, 40.1 (19.2), 35.8	17, 31.7 (8.2), 30.4	18, 20.1 (7.1), 20.7
51-60 yrs	**Right**	21, 18.9 (9.3), 17.3	21, 31.7 (19.8), 28.3	19, 24.2 (7.7), 23.0	20, 16.3 (13.1), 12.1
	Left	21, 21.1 (12.6), 19.2	21, 33.2 (15.6), 28.7	21, 24.2 (7.0), 23.1	21, 14.3 (10.7), 10.6
		SNAP amplitude in μV for female subjects by age group in Naini			
⩽30 yrs	**Right**	24, 35.5 (20.3), 28.7	23, 54.4 (29.4), 38.3	24, 36.0 (11.5), 32.4	24, 26.4 (10.1), 24.0
	Left	24, 37.9 (19.8), 29.9	24, 62.5 (35.2), 60.0	24, 36.5 (11.6), 35.5	23, 25.8 (9.3), 23.5
31-40 yrs	**Right**	20, 40.2 (12.7), 41.7	19, 51.6 (21.5), 47.7	20, 35.4 (12.0), 35.4	19, 22.8 (13.8), 17.8
	Left	19, 44.0 (20.5), 43.4	18, 65.9 (25.0), 69.4	19, 34.4 (11.1), 34.2	19, 21.5 (11.6), 16.3
41-50 yrs	**Right**	17, 34.3 (15.5), 29.5	17, 46.1 (15.9), 52.3	17, 32.9 (9.6), 32.8	17, 23.3 (13.4), 19.3
	Left	17, 39.0 (15.0), 36.0	17, 51.9 (16.2), 49.3	17, 33.6 (11.8), 31.0	17, 21.2 (8.0), 20.1
51-60 yrs	**Right**	15, 21.4 (8.9), 19.7	17, 34.3 (15.4), 33.5	17, 24.1 (6.3), 22.8	17, 15.7 (4.0), 16.0
	Left	17, 25.9 (12.5), 23.7	17, 45.1 (25.6), 45.4	17, 26.1 (7.5), 25.0	17, 17.5 (15.2), 12.7

Table 2C. N, mean, standard deviation and median for proximal MNC velocity and amplitude by nerve, centre, sex, age group & side.

Age Group	Side	Ulnar	Median	Common Peroneal	Ulnar	Median	Common Peroneal
		Proximal MNC velocity in m/sec for male subjects in Faizabad			**Proximal CMAP amplitude in mV for male subjects in Faizabad**		
≤30 yrs	Right	19, 66.1 (3.7), 65.4	19, 67.5 (4.8), 68.4	19, 58.8 (5.7), 58.2	19, 13.3 (2.7), 13.3	19, 15.5 (3.3), 16.1	19, 8.7 (3.7), 8.0
	Left	18, 65.1 (3.3), 64.8	18, 67.1 (5.7), 66.4	18, 58.8 (4.9), 58.4	18, 13.9 (4.2), 13.4	18, 17.6 (4.1), 16.5	18, 9.4 (4.2), 10.5
31-40 yrs	Right	20, 62.5 (4.8), 62.7	20, 65.1 (3.4), 64.5	20, 57.2 (6.7), 54.8	20, 13.5 (3.0), 13.0	20, 16.2 (4.1), 15.6	20, 7.4 (2.0), 7.3
	Left	20, 61.6 (5.5), 63.1	19, 65.6 (4.3), 64.8	19, 56.6 (4.2), 57.7	20, 13.1 (2.7), 13.5	19, 17.4 (4.5), 16.9	19, 7.1 (2.3), 6.8
41-50 yrs	Right	19, 61.0 (4.2), 60.4	19, 61.5 (4.6), 61.9	19, 53.5 (5.3), 52.5	19, 11.8 (3.2), 12.3	19, 14.8 (4.2), 13.4	19, 6.5 (2.7), 6.0
	Left	19, 60.6 (3.5), 61.3	18, 62.9 (3.8), 63.2	19, 54.3 (5.0), 53.8	19, 11.7 (2.8), 12.1	18, 16.3 (4.7), 16.1	19, 6.3 (2.8), 5.8
51-60 yrs	Right	19, 56.1 (4.2), 55.7	20, 59.0 (5.3), 59.2	19, 50.6 (5.1), 50.8	19, 11.2 (3.5), 10.8	20, 13.0 (4.2), 13.4	19, 5.7 (2.6), 5.1
	Left	20, 57.9 (5.1), 59.3	20, 59.8 (4.3), 60.7	20, 50.9 (5.6), 51.0	20, 10.7 (3.5), 10.4	20, 12.7 (2.9), 12.7	20, 5.7 (2.4), 5.6
		Proximal MNC velocity in m/sec for female subjects in Faizabad			**Proximal CMAP amplitude in mV for female subjects in Faizabad**		
≤30 yrs	Right	20, 66.6 (5.5), 65.1	21, 66.2 (5.1), 66.6	21, 61.0 (5.9), 59.1	20, 14.3 (3.3), 13.5	21, 16.6 (4.4), 16.4	21, 8.9 (2.6), 8.8
	Left	21, 65.6 (4.7), 65.6	21, 67.5 (5.4), 66.8	21, 61.9 (5.4), 60.3	21, 15.1 (3.7), 15.4	21, 17.0 (5.1), 16.4	21, 8.5 (3.0), 8.6
31-40 yrs	Right	20, 65.5 (5.8), 66.4	20, 66.4 (3.7), 66.7	19, 60.5 (6.0), 60.4	20, 13.6 (3.4), 12.6	20, 16.2 (3.7), 16.5	19, 6.7 (2.2), 6.9
	Left	19, 65.2 (3.1), 66.7	19, 66.2 (6.0), 65.2	20, 58.3 (5.6), 57.5	19, 13.8 (3.1), 13.3	20, 16.1 (4.2), 16.4	20, 6.5 (2.6), 6.2
41-50 yrs	Right	21, 65.0 (5.8), 64.4	20, 63.0 (5.1), 62.6	20, 55.9 (4.5),56.4	21, 13.4 (2.6), 13.7	20, 14.5 (4.3), 14.3	20, 6.9 (2.8), 7.0
	Left	20, 63.9 (5.3), 64.1	21, 63.8 (5.5), 64.1	20, 57.6 (3.5), 58.5	20, 13.0 (3.3), 12.7	21, 15.5 (4.2), 16.2	20, 7.0 (2.5), 7.3
51-60 yrs	Right	18, 62.1 (4.6), 62.4	18, 61.7 (6.0), 62.9	16, 54.9 (5.3), 54.9	18, 12.5 (2.4), 12.8	18, 12.8 (3.4), 12.4	16, 6.3 (3.0), 6.3
	Left	17, 62.3 (4.7), 63.8	18, 61.9 (5.2), 61.0	17, 54.5 (4.1), 54.4	17, 11.9 (3.0), 11.9	18, 11.9 (4.4), 11.7	17, 6.1 (2.4), 6.0
		Proximal MNC velocity in m/sec for male subjects in Naini			**Proximal CMAP amplitude in mV for male subjects in Naini**		
≤30 yrs	Right	20, 64.3 (5.1), 64.2	19, 63.8 (7.6), 63.5	18, 65.9 (10.5), 64.4	20, 17.3 (3.0), 17.0	20, 21.0 (5.1), 21.5	18, 10.6 (3.2), 10.0
	Left	19, 67.1 (5.5), 66.9	18, 67.8 (6.1), 67.0	20, 63.1 (7.3), 62.4	19, 18.3 (3.1), 19.2	18, 18.2 (4.4), 19.2	20, 10.0 (4.9), 8.9
31-40 yrs	Right	19, 61.0 (4.4), 60.9	19, 60.0 (5.4), 59.4	19, 59.9 (4.6), 59.0	19, 16.0 (3.4), 16.5	19, 16.6 (4.7), 15.5	19, 8.2 (3.3), 7.2
	Left	19, 60.8 (3.6), 59.8	19, 61.5 (2.8), 63.2	19, 58.1 (5.1), 57.3	19, 16.4 (4.2), 16.0	19, 17.5 (5.0), 17.7	19, 8.5 (3.0), 7.6
41-50 yrs	Right	18, 60.9 (5.6), 61.4	17, 61.5 (5.0), 61.9	17, 59.2 (7.8), 61.3	18, 16.1 (4.3), 15.5	17, 16.4 (6.3), 15.3	17, 7.4 (3.6), 6.7
	Left	17, 64.2 (5.0), 63.3	16, 64.3 (4.6), 66.0	16, 57.3 (6.3), 57.3	17, 15.6 (3.6), 14.7	17, 15.9 (7.0), 14.4	17, 7.1 (2.4), 6.7
51-60 yrs	Right	21, 57.1 (5.5), 56.2	21, 60.6 (7.5), 60.9	19, 54.0 (8.0), 52.2	21, 14.0 (2.4), 13.2	21, 13.7 (4.8), 13.2	20, 7.4 (3.3), 7.2
	Left	20, 58.6 (4.8), 57.6	21, 60.4 (6.4), 60.1	21, 54.0 (7.3), 53.4	20, 15.5 (3.1), 15.5	21, 13.8 (3.0), 13.8	21, 7.4 (3.7), 7.1
		Proximal MNC velocity in m/sec for female subjects in Naini			**Proximal CMAP amplitude in mV for female subjects in Naini**		
≤30 yrs	Right	22, 64.5 (4.4), 65.5	23, 63.0 (4.6), 62.1	24, 63.2 (5.5), 63.3	23, 18.2 (3.9), 18.5	23, 17.4 (5.1), 15.9	24, 9.8 (2.9), 9.5
	Left	22, 64.5 (5.1), 64.9	24, 62.1 (6.3), 60.5	24, 64.7 (5.6), 66.4	23, 17.1 (4.4), 17.7	24, 17.2 (5.0), 16.3	24, 8.7 (3.2), 8.1
31-40 yrs	Right	19, 62.7 (5.7), 63.5	19, 61.2 (3.7), 61.6	18, 63.0 (6.9), 63.6	19, 18.9 (4.6), 18.5	20, 17.8 (5.7), 17.4	19, 8.7 (3.8), 7.2
	Left	17, 64.0 (5.7), 65.2	18, 62.2 (5.3), 61.7	17, 61.3 (7.1), 63.4	17, 18.7 (3.6), 18.3	18, 18.2 (5.5), 18.2	17, 8.0 (2.6), 8.3
41-50 yrs	Right	17, 58.8 (5.5), 59.3	16, 58.1 (4.6), 58.0	17, 58.1 (6.0), 56.2	17, 16.4 (3.7), 15.6	16, 15.4 (3.7), 14.6	17, 7.4 (1.9), 7.1
	Left	16, 59.5 (5.7), 58.7	17, 60.5 (4.4), 60.5	15, 58.8 (5.3), 58.7	17, 16.5 (3.1), 16.2	17, 15.9 (3.1), 15.0	15, 8.3 (3.0), 7.1
51-60 yrs	Right	17, 61.4 (5.6), 61.5	17, 59.4 (5.9), 58.4	14, 57.1 (5.1), 56.6	17, 16.2 (3.6), 16.5	17, 13.9 (4.1), 12.4	14, 7.1 (1.8), 6.9
	Left	17, 62.1 (4.9), 63.4	17, 61.0 (8.6), 57.0	17, 58.7 (5.1), 58.7	17, 14.4 (3.0), 14.7	17, 14.8 (3.5), 15.8	17, 6.6 (2.2), 6.3

Table 2D. N, mean, standard deviation and median for distal MNC latency and amplitude by nerve, centre, sex, age group and side

Age Group	Side	Ulnar	Median	Common Peroneal	Ulnar	Median	Common Peroneal
		Distal MNC latency in msec for male subjects in Faizabad			**Distal MNC amplitude in mV for male subjects in Faizabad**		
≤30 yrs	**Right**	19, 2.4 (0.4), 2.4	19, 3.1 (0.5), 3.1	19, 3.8 (0.7), 3.7	19, 14.3 (2.9), 14.0	19, 15.4 (3.5), 15.9	19, 9.5 (3.8), 9.3
	Left	18, 2.5 (0.4), 2.6	18, 3.1 (0.4), 3.0	18, 3.6 (0.7), 3.5	18, 14.8 (4.4), 14.9	18, 19.2 (4.2), 18.2	18, 10.4 (4.5), 10.6
31-40 yrs	**Right**	19, 2.5 (0.3), 2.5	20, 3.4 (0.3), 3.4	20, 3.9 (0.9), 3.6	19, 14.5 (3.3), 14.1	20, 17.1 (3.8), 17.4	20, 8.3 (2.1), 7.9
	Left	19, 2.6 (0.3), 2.6	19, 3.4 (0.3), 3.4	20, 3.6 (0.6), 3.4	19, 14.3 (2.7), 14.9	19, 18.6 (4.3), 18.3	20, 8.3 (2.2), 8.0
41-50 yrs	**Right**	19, 2.5 (0.3), 2.5	19, 3.2 (0.4), 3.3	19, 3.6 (0.8), 3.5	19, 12.7 (3.5), 11.7	19, 16.4 (4.0), 15.9	19, 7.5 (2.8), 7.0
	Left	19, 2.5 (0.3), 2.5	18, 3.2 (0.3), 3.3	18, 3.3 (0.5), 3.3	19, 12.9 (3.2), 13.1	18, 17.9 (4.2), 18.4	18, 7.2 (2.9), 7.0
51-60 yrs	**Right**	20, 2.7 (0.4), 2.8	20, 3.3 (0.5), 3.3	20, 3.9 (1.1), 3.6	20, 12.8 (4.0), 13.7	20, 14.8 (4.2), 14.5	20, 6.0 (3.0), 5.7
	Left	20, 2.7 (0.4), 2.6	19, 3.2 (0.3), 3.3	19, 3.6 (0.5), 3.4	20, 12.0 (3.7), 11.6	19, 15.0 (2.9), 15.6	19, 6.8 (2.5), 7.4
		Distal MNC latency in msec for female subjects in Faizabad			**Distal MNC amplitude in mV for female subjects in Faizabad**		
≤30 yrs	**Right**	21, 2.5 (0.4), 2.4	21, 3.0 (0.4), 3.0	21, 3.5 (0.5), 3.4	21, 15.0 (3.4), 14.6	21, 17.6 (4.2), 16.4	21, 9.9 (2.6), 10.5
	Left	21, 2.4 (0.4), 2.4	21, 3.1 (0.5), 3.1	21, 3.3 (0.7), 3.3	21, 16.0 (3.9), 15.6	21, 18.3 (5.3), 18.5	21, 9.0 (3.3), 9.0
31-40 yrs	**Right**	20, 2.3 (0.4), 2.3	20, 3.0 (0.4), 3.0	20, 3.2 (0.5), 3.1	20, 14.8 (3.9), 13.6	20, 19.4 (3.4), 20.1	20, 7.3 (2.3), 7.6
	Left	20, 2.4 (0.3), 2.3	20, 3.0 (0.4), 3.0	20, 3.1 (0.5), 3.1	20, 14.8 (3.3), 14.9	20, 18.2 (4.3), 18.7	20, 7.5 (3.0), 6.7
41-50 yrs	**Right**	21, 2.4 (0.4), 2.4	21, 3.0 (0.5), 2.9	20, 3.5 (0.6), 3.4	21, 14.9 (2.7), 15.0	21, 16.4 (4.3), 16.2	20, 7.8 (2.9), 7.5
	Left	21, 2.4 (0.3), 2,4	21, 3.1 (0.5), 3.0	20, 3.2 (0.4), 3.1	21, 14.2 (3.2), 13.9	21, 17.6 (3.9), 17.5	20, 8.4 (2.6), 8.8
51-60 yrs	**Right**	18, 2.5 (0.4), 2.6	18, 3.3 (0.6), 3.3	18, 3.3 (0.7), 3.1	18, 13.6 (2.2), 13.6	18, 14.5 (3.6), 14.0	18, 7.4 (3.2), 7.8
	Left	18, 2.4 (0.3), 2.5	18, 3.3 (0.4), 3.4	17, 3.3 (0.6), 3.4	18, 13.4 (3.2), 13.5	18, 13.9 (4.3), 15.0	17, 7.2 (2.9), 6.2
		Distal MNC latency in msec for male subjects in Naini			**Distal MNC amplitude in mV for male subjects in Naini**		
≤30 yrs	**Right**	20, 2.8 (0.5), 2.9	19, 3.5 (0.6), 3.4	19, 4.5 (0.8), 4.4	20, 18.6 (3.2), 18.4	19, 21.4 (5.1), 22.0	19, 11.3 (3.7), 10.0
	Left	19, 2.8 (0.5), 2.8	19, 3.6 (0.7), 3.7	20, 4.5 (0.9), 4.5	19, 19.8 (2.6), 19.3	19, 20.0 (4.9), 21.2	20, 10.9 (5.2), 10.7
31-40 yrs	**Right**	19, 2.7 (0.5), 2.6	19, 3.5 (0.7), 3.5	19, 4.4 (1.2), 4.3	19, 17.1 (3.5), 17.0	19, 17.3 (5.0), 16.6	19, 9.4 (3.6), 8.7
	Left	19, 2.7 (0.5), 2.7	19, 3.4 (0.6), 3.3	18, 4.0 (0.9), 4.0	19, 17.8 (4.0), 16.7	19, 17.9 (5.0), 18.5	18, 9.8 (3.1), 8.9
41-50 yrs	**Right**	18, 2.8 (0.4), 3.0	18, 3.5 (0.4), 3.5	18, 4.3 (1.1), 3.9	18, 17.5 (4.5), 17.0	18, 17.4 (6.3), 16.1	18, 7.8 (3.8), 7.4
	Left	18, 2.8 (0.5), 2.7	18, 3.5 (0.6), 3.5	17, 3.9 (1.1), 4.1	18, 16.8 (3.3), 15.4	18, 16.9 (7.1), 16.1	17, 8.2 (2.6), 8.1
51-60 yrs	**Right**	20, 2.8 (0.5), 2.7	21, 3.8 (0.5), 3.8	20, 4.0 (0.8), 4.1	20, 15.2 (2.8), 13.9	21, 14.6 (4.6), 14.1	20, 8.7 (3.7), 8.2
	Left	21, 2.8 (0.3), 2.8	21, 3.8 (0.5), 3.9	21, 3.9 (1.1), 3.6	21, 17.0 (2.9), 16.8	21, 15.1 (3.3), 15.0	21, 8.3 (4.0), 7.9
		Distal MNC latency in msec for female subjects in Naini			**Distal MNC amplitude in mV for female subjects in Naini**		
≤30 yrs	**Right**	24, 2.6 (0.5), 2.6	22, 3.3 (0.5), 3.4	24, 3.8 (0.8), 3.7	24, 19.0 (4.5), 19.7	22, 19.7 (5.2), 18.3	24, 10.8 (2.9), 10.4
	Left	22, 2.5 (0.4), 2.4	23, 3.3 (0.5), 3.2	24, 3.8 (0.8), 3.7	22, 18.7 (4.4), 18.6	23, 18.6 (5.1), 18.8	24, 9.4 (3.2), 8.8
31-40 yrs	**Right**	19, 2,5 (0.5), 2.5	17, 3.3 (0.6), 3.2	20, 3.3 (0.7), 3.2	19, 20.1 (4.3), 20.5	17, 19.7 (6.2), 19.5	20, 9.4 (3.8), 7.8
	Left	19, 2.6 (0.6), 2.6	18, 3.4 (0.7), 3.0	18, 3.6 (0.8), 3.5	19, 20.9 (4.6), 20.2	18, 19.4 (5.9), 18.8	18, 9.2 (2.8), 9.1
41-50 yrs	**Right**	17, 2.6 (0.4), 2.7	17, 3.4 (0.6), 3.5	17, 3.6 (0.9), 3.6	17, 17.8 (3.8), 17.0	17, 16.1 (3.5), 15.6	17, 8.1 (2.3), 7.6
	Left	17, 2.7 (0.4), 2.7	17, 3.5 (0.5), 3.5	16, 3.7 (1.0), 3.8	17, 17.9 (3.1), 17.8	17, 16.9 (3.5), 16.2	16, 8.8 (3.3), 7.9
51-60 yrs	**Right**	17, 2.7 (0.4), 2.7	17, 3.5 (0.5), 3.6	15, 3.3 (0.6), 3.3	17, 17.7 (3.6), 17.3	17, 14.7 (4.1), 14.4	15, 7.4 (2.3), 7.5
	Left	17, 2.6 (0.4), 2.5	17, 3.6 (0.6), 3.4	17, 3.6 (0.5), 3.8	17, 15.6 (3.0), 15.0	17, 15.6 (3.7), 15.4	17, 7.2 (2.2), 7.2

Table 3A. Normal reference values for sensory nerve conduction velocity and amplitude for five nerves based on the 95th percentile, presented as mid-points of four 10 year age bands and calculated by sex, by centre and by combined centres.

	Ulnar				Median				Radial Cutaneous				Sural			
	SNCV in m/sec		SNAP in µV		SNCV in m/sec		SNAP in µV		SNCV in m/sec		SNAP in µV		SNCV in m/sec		SNAP in µV	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Faizabad																
25 years	48.75	50.60	13.31	12.52	45.09	47.57	21.45	18.77	52.13	54.25	16.87	16.27	45.62	49.25	13.73	11.72
35 years	48.20	50.14	11.58	11.59	45.32	46.05	18.92	16.54	52.41	54.34	15.65	16.23	46.88	50.77	11.87	9.87
45 years	47.69	49.71	10.01	10.75	45.59	44.55	16.54	14.47	52.74	54.48	14.54	16.24	48.18	52.29	10.30	8.20
55 years	47.21	49.32	8.58	10.00	45.91	43.08	14.31	12.53	53.14	54.69	13.54	16.30	49.51	53.82	8.96	6.71
Naini																
25 years	40.58	44.11	14.91	14.63	41.51	44.93	12.35	22.98	46.10	46.52	16.72	20.54	39.92	40.53	8.87	11.93
35 years	41.17	44.04	11.61	12.92	42.24	44.65	12.84	19.46	47.20	46.82	16.23	18.68	40.64	41.11	7.54	10.74
45 years	41.80	44.00	8.80	11.36	43.03	44.41	10.52	16.27	48.39	47.16	15.78	17.00	41.41	41.72	6.36	9.76
55 years	42.47	44.00	6.40	9.95	43.85	44.20	8.39	13.37	49.66	47.53	15.37	15.47	42.26	42.37	5.31	8.94
Combined																
25 years	42.88	45.89	14.05	13.53	42.48	45.31	17.65	20.95	46.96	47.99	16.69	18.31	40.36	42.05	10.53	11.48
35 years	43.10	45.78	11.55	12.27	43.11	44.62	15.17	18.10	45.71	48.40	15.88	17.32	41.27	43.14	9.03	9.96
45 years	43.33	45.69	9.32	11.11	43.76	43.94	12.81	15.43	46.78	48.83	15.12	16.38	42.22	44.26	7.69	8.61
55 years	43.59	45.62	7.34	10.03	44.43	43.29	10.58	12.94	47.88	49.29	14.43	15.49	43.23	45.39	6.50	7.42

Table 3B. Normal reference values for proximal motor nerve conduction velocity and amplitude for three nerves based on the 95th and 5th percentiles respectively, presented as mid-points of four 10 year age bands and calculated by sex, by centre and by combined centres.

	Ulnar				Median				Peroneal			
	MNCV in m/sec		CMAP in mV		MNCV in m/sec		CMAP in mV		MNCV in m/sec		CMAP in mV	
	M	F	M	F	M	F	M	F	M	F	M	F
Faizabad												
25 years	58.25	58.04	8.39	9.64	60.12	58.07	10.49	9.90	50.48	52.82	4.04	3.74
35 years	55.66	56.98	7.66	9.17	57.64	56.49	9.52	8.85	48.18	51.28	3.39	3.28
45 years	52.96	55.95	6.96	8.73	55.15	54.93	8.59	7.83	45.99	49.87	2.80	2.85
55 years	50.16	54.96	6.28	8.32	52.65	53.37	7.71	6.85	43.90	48.56	2.26	2.45
Naini												
25 years	55.99	54.78	12.04	11.96	54.57	54.15	11.26	10.87	51.64	53.82	4.41	4.92
35 years	54.36	53.24	11.32	11.36	53.61	53.38	10.03	10.34	49.34	52.35	3.88	4.58
45 years	52.81	51.68	10.66	10.79	52.70	52.66	8.92	9.87	47.23	50.97	3.40	4.28
55 years	51.36	50.10	10.03	10.25	51.84	51.99	7.93	9.44	45.29	49.66	2.97	4.00
Combined												
25 years	56.86	56.19	9.54	10.28	56.78	55.33	10.88	10.22	50.73	53.14	4.17	4.24
35 years	54.81	55.03	8.75	9.76	55.16	54.31	9.78	9.41	48.49	51.66	3.58	3.81
45 years	52.80	53.86	7.99	9.26	53.59	53.31	8.75	8.64	46.42	50.28	3.04	3.41
55 years	50.82	52.70	7.25	8.78	52.07	52.34	7.79	7.91	44.51	48.98	2.55	3.03

Table 3C. Normal reference values for distal motor nerve conduction latency and amplitude for three nerves based on the 5th or 95th percentiles, presented as mid-points of four 10 year age bands and calculated by sex, by centre and by combined centres.

	Ulnar				Median				Peroneal			
	CMAP Latency in msec		CMAP Amplitude in mV		CMAP Latency in msec		CMAP Amplitude in mV		CMAP Latency in msec		CMAP Amplitude in mV	
	M	F	M	F	M	F	M	F	M	F	M	F
Faizabad												
25 years	2.99	3.04	8.91	10.42	3.81	3.86	11.23	11.47	5.10	4.32	4.85	4.09
35 years	3.05	3.06	8.29	10.11	3.85	3.93	10.66	10.49	5.10	4.31	4.07	3.71
45 years	3.10	3.08	7.70	9.81	3.89	4.00	10.12	9.54	5.08	4.30	3.36	3.35
55 years	3.15	3.09	7.14	9.54	3.92	4.07	9.61	8.61	5.06	4.28	2.71	3.00
Naini												
25 years	3.57	3.39	13.52	13.10	4.47	4.28	11.95	12.13	6.31	5.15	4.81	5.47
35 years	3.57	3.41	12.89	12.52	4.54	4.36	10.68	11.36	6.08	5.04	4.29	5.01
45 years	3.56	3.43	12.30	11.98	4.61	4.43	9.51	10.66	5.85	4.92	3.81	4.60
55 years	3.56	3.45	11.77	11.46	4.68	4.52	8.44	10.02	5.61	4.81	3.37	4.22
Combined												
25 years	3.33	3.25	10.43	11.16	4.23	4.11	11.58	11.76	5.91	4.81	4.76	4.74
35 years	3.37	3.26	9.67	10.72	4.29	4.18	10.65	10.88	5.75	4.74	4.12	4.30
45 years	3.40	3.28	8.93	10.30	4.35	4.25	9.77	10.04	5.60	4.66	3.54	3.87
55 years	3.43	3.30	8.21	9.91	4.41	4.33	8.93	9.26	5.44	4.59	3.00	3.47

Figure 1. Scatter plots of ulnar sensory nerve conduction amplitude and proximal and distal motor nerve conduction amplitude for normal subjects by age and by sex with 5th percentile based on combined centres plus shaded area highlighting the difference between centre-specific 5th percentiles.

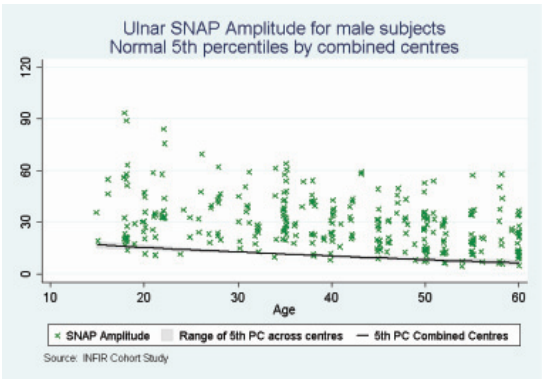

Chart 1A

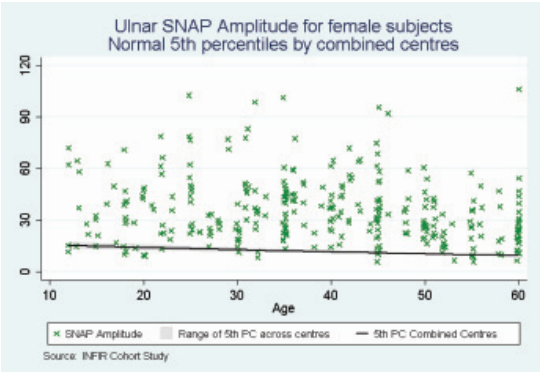

Chart 1B

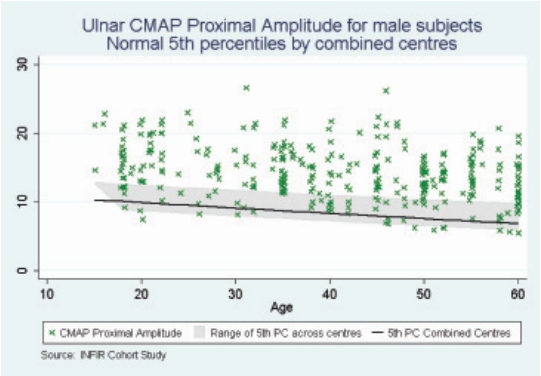

Chart 1C

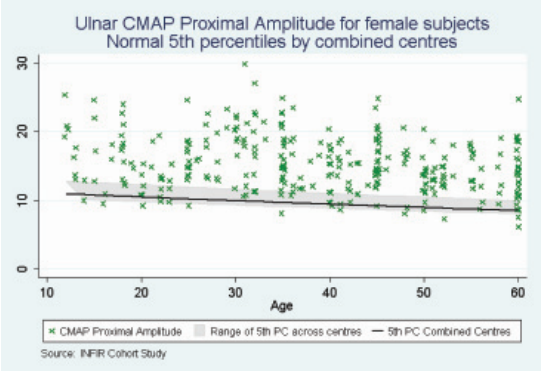

Chart 1D

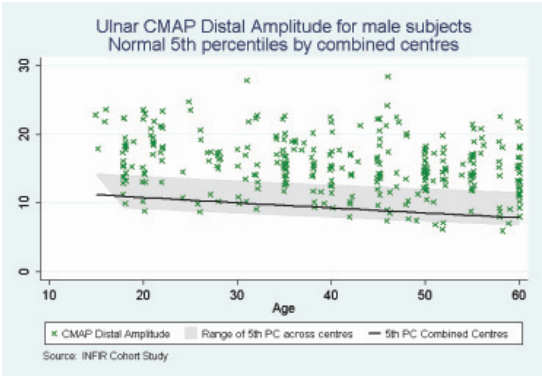

Chart 1E

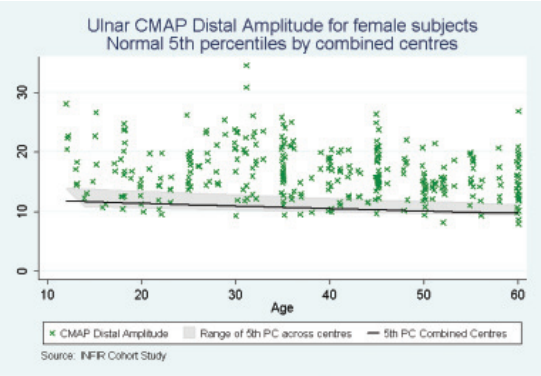

Chart 1F

Scatter plots and a full set of summary statistics, including additional 97.5th and 99th percentile, for all nerves and functions are available from the authors.

DISCUSSION

Conclusions based on NCS testing for neuropathy require comparison of individual results with established reference values. In this study we collected data from subjects representative of the

Table 4. Percentage impairment rates for SNCV, SNAP amplitude, MNCV and proximal and distal CMAP amplitude and latency in five nerves among 303 newly diagnosed cases of MB leprosy, by sex, by centre and for combined centres.

	Ulnar				Median				Radial Cutaneous				Peroneal				Sural			
	SNCV		SNAP Amplitude		SNCV		SNAP Amplitude		SNCV		SNAP Amplitude		SNCV		SNAP Amplitude		SNCV		SNAP Amplitude	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Faizabad	36.1	25.8	46.2	33.3	19.2	25.8	40.4	30.3	40.6	44.3	59.4	62.9					53.2	50.0	66.7	62.5
Naini	20.4	25.6	45.4	32.1	21.3	28.2	31.3	34.6	32.5	37.3	59.2	61.3					54.0	52.0	65.1	72.0
Combined	28.9	25.0	45.0	31.9	20.5	26.4	35.3	32.6	33.8	39.3	58.3	63.4					52.2	51.7	65.3	65.3

	Ulnar				Median				Radial Cutaneous				Peroneal				Sural			
	MNCV		CMAP Amplitude		MNCV		CMAP Amplitude						MNCV		CMAP Amplitude					
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Faizabad	36.5	21.0	28.4	17.7	25.3	14.5	20.5	19.4					22.3	18.8	28.4	28.1				
Naini	49.6	20.5	39.6	29.5	19.3	7.7	26.5	41.0					27.2	26.0	42.1	50.6				
Combined	45.6	22.1	27.6	20.7	21.9	12.9	24.2	28.6					23.5	22.0	35.5	39.0				

	Ulnar				Median				Radial Cutaneous				Peroneal				Sural			
	CMAP Latency		CMAP Amplitude		MNCV Latency		CMAP Amplitude						MNCV Latency		CMAP Amplitude					
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Faizabad	26.0	12.9	17.1	11.3	13.0	17.8	17.8	21.0					17.7	22.2	31.3	28.6				
Naini	17.5	16.7	32.5	23.1	11.8	10.3	25.6	39.7					11.9	10.4	41.3	44.2				
Combined	21.8	14.3	17.6	14.3	14.3	15.7	22.7	31.4					16.5	18.6	36.6	37.1				

Figure 2. Scatter plots of ulnar SNAP amplitude and ulnar CMAP distal and motor amplitude for cohort cases by sex and by age with 5th percentile based on combined centres plus shaded area highlighting the difference between centre-specific 5th percentiles.

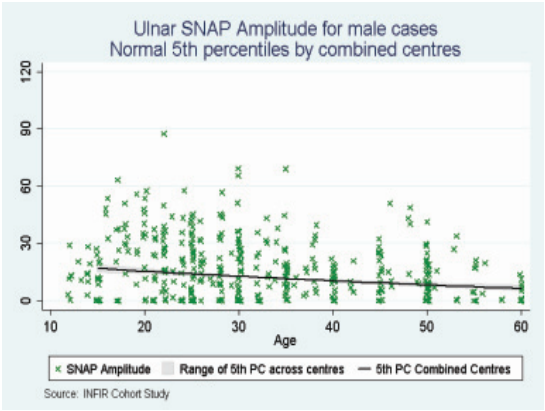

Chart 2A

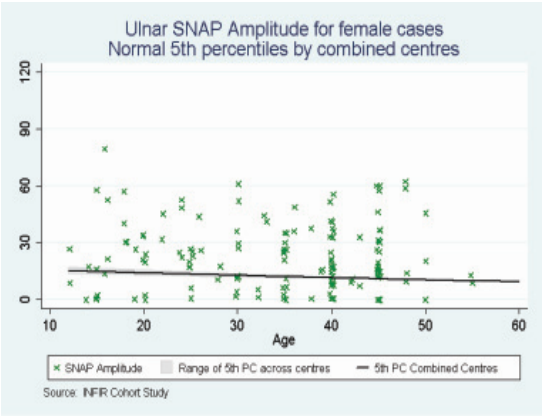

Chart 2B

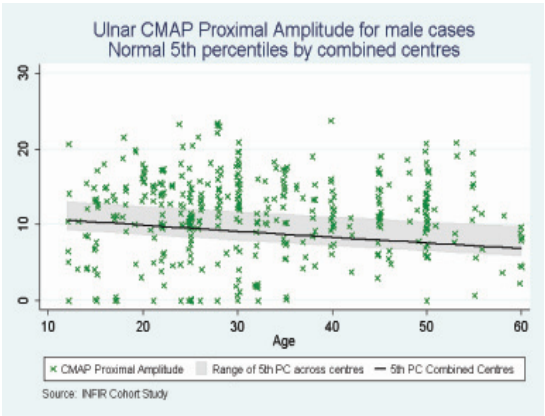

Chart 2C

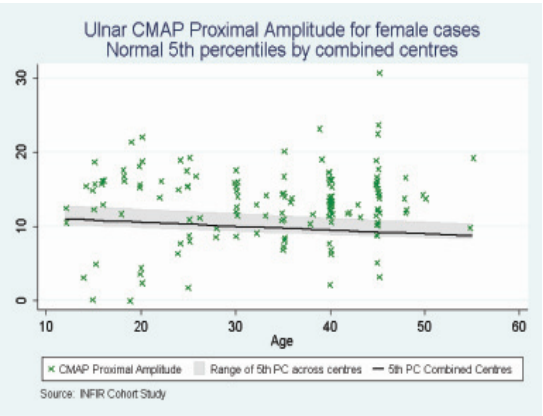

Chart 2D

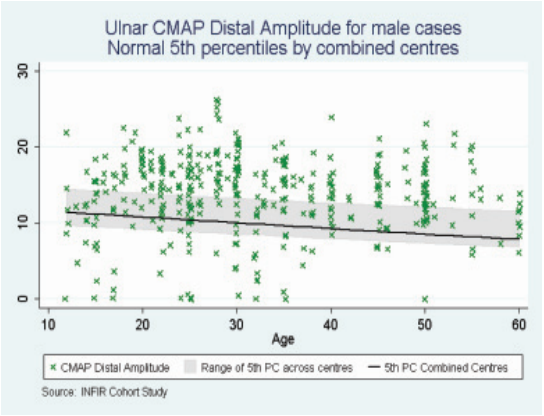

Chart 2E

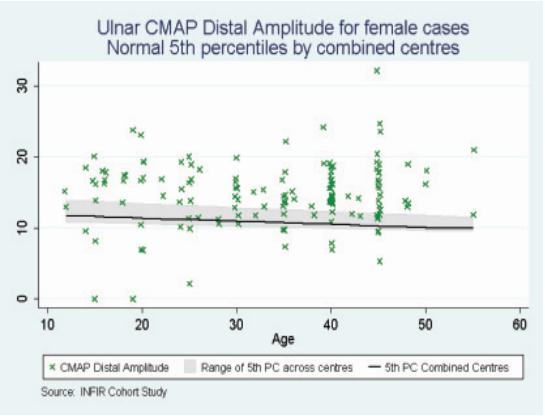

Chart 2F

local population. To best define the limits of normal nerve function, reference values were calculated to include adjustment for known covariates and centre-related differences. In the absence of left and right side differences, merging data from right and left side assessments gave greater precision in the estimation of the reference values at each test site. These may now be used to assess nerve function in individuals for whom peripheral nerve function is at risk. The mean values of SNAP amplitude and SNCV and proximal and distal CMAP latency and amplitude and MNCV in the present study correspond well with previous studies.[16,17] The sources and implications of differences between centres have been discussed in the earlier papers in this series.[14,,15]

Reference values based on percentiles were derived by regression-based methods, and are not therefore directly comparable with earlier published work defining abnormality as two or greater standard deviations from the mean. Like many diagnostic tools with moderate sensitivity and specificity, it is advised that values "close" to the published reference value are not necessarily an indication of abnormality.[18] However, a progression towards and beyond the reference value represents a new stage in nerve involvement that is likely to be of clinical importance.

Skin temperatures recorded in Faizabad ranged from 28.0˚C to 36.9˚C for hands and from 23.0˚C to 36.4˚C for the foot. The equivalent in Naini were 24.0˚C to 36.1˚C and 18.0˚C to 35.0˚C. In addition to the standard temperature correction we carried out a series of analyses exploring any remaining relationship between skin temperature and amplitude and velocity. In all nerves and test sites for both sensory and motor nerve conduction we found skin temperature to be predictive of amplitude ($p<0.001$ in each case). We also looked for any continuing association between skin temperature and temperature-adjusted measures of SNCV, MNCV, and SNAP and CMAP amplitudes and latencies. While significance levels were generally lower, we found statistically significant temperature-related variation in all measures. The suggestion from these findings is that the chosen approach to temperature adjustment was only partially successful in removing the temperature effect. In a smaller study this effect may not have been detectable. Further analysis of the present data may identify a more sensitive method of adjustment.

The reference values reported here were used to assess the nerve status of newly diagnosed cases of multibacillary leprosy recruited to the Cohort study. In relation to sensory nerve conduction our findings match those of Arruda *et al*[19] who found high rates of abnormality in sural nerve sensory action potential while conduction velocity was only mildly involved. Our findings also reinforce those of Husain and Malaviya[20] who compared patients with and without manifest nerve damage and found reduced nerve conduction velocities and changes in latency and amplitude. Changes in sensory nerve conduction were most pronounced. We found high impairment rates in lower limbs and also in the radial cutaneous nerve. Soysal *et al*[21], working in Turkey, used nerve conduction to assess a series of newly-diagnosed leprosy patients. They found that sensory impairment predominated over motor and identified predominantly axonal polyneuropathy that was more severe in the lower extremities. Sensory nerve damage was accompanied by autonomic involvement. Together with the level of impaired function observed in the leprosy cohort, these findings raise issues concerning treatment of these early indicators of nerve involvement and the choice of an appropriate treatment regime.

In conclusion, this is the first large-scale study to publish reference values for a full set of nerve conduction parameters for a normal population in northern India. The reference values represent the limit to normal assessments for sensory and motor nerve conduction velocity and amplitude by sex and within 4 ten year age bands. While the research was conducted in preparation for a prospective study of people affected by leprosy, the data have potential applications in the assessment of nerve function in a wide range of neurological conditions.

Applying these reference values to the data from the leprosy cohort draws attention to the high rates of impaired function among people affected by leprosy. Further analysis of the Cohort data will determine whether the presence of such impairment at diagnosis is a risk factor for the development of new impairment detectable by monofilament or muscle testing during and subsequent to treatment with multi-drug therapy. Questions also arise about the need for early treatment and the choice of an appropriate treatment regime.

ACKNOWLEDGEMENTS

We are grateful to the people who agreed to participate as subjects in the research reported here. The staff at the TLM hospitals in Naini and Faizabad have been invaluable. We also gratefully

acknowledge the financial support of Follereau Luxembourg, LEPRA UK and The Leprosy Mission International, without which this study would have been impossible.

We wish to thank the staff of the LEPRA offices in Hyderabad and Colchester and the TLM offices in Delhi and London for their administrative support. The INFIR Cohort Study is a result of extensive collaboration between Fondation Luxembourgeoise Raoul Follereau (FL), LEPRA UK, LEPRA India, The Leprosy Mission International (TLMI), The Leprosy Mission India, the London School of Hygiene & Tropical Medicine and Aberdeen University Department of Public Health.

REFERENCES

1. Dorfman LJ, Robinson LR. AAEM minimonograph #47: normative data in electrodiagnostic medicine. ff. *Muscle Nerve* 1997; 20(1):4-14.
2. Tong HC, Werner RA, Franzblau A. Effect of aging on sensory nerve conduction study parameters. *Muscle Nerve* 2004; 29(5):716-20.
3. Dyck PJ, Davies JL, Litchy WJ, *et al*. Longitudinal assessment of diabetic polyneuropathy using a composite score in the Rochester Diabetic Neuropathy Study cohort. *Neurology*1997; 49(1):229-39.
4. Wang SH, Robinson LR. Considerations in reference values for nerve conduction studies. *Phys Med Rehabil Clin N Am* 1998; 9(4):907-23, viii.
5. Van Brakel WH, Anderson AM, Withington SG, *et al*. The prognostic importance of detecting mild sensory impairment in leprosy: a randomized controlled trial (TRIPOD 2). *Lepr Rev* 2003; 74(4):300-10.
6. Van Brakel WH, Nicholls PG, Das L, *et al*. The INFIR Cohort Study: assessment of sensory and motor neuropathy in leprosy at baseline. *Lepr Rev* 2005; 76:277-95.
7. van Brakel WH, Nicholls PG, Das L, *et al.*, The INFIR Cohort Study: investigating prediction, detection and pathogenesis of neuropathy and reactions in leprosy. Methods and baseline results of a cohort of multibacillary leprosy patients in north India.[erratum appears in *Lepr Rev* 2005; 76(3):264]. *Lepr Rev* 2005; 76(1):14-34.
8. Roberts AE, Nicholls PG, Maddali P, van Brakel WH. Ensuring inter-tester reliability of voluntary muscle and monofilament sensory testing in the INFIR Cohort Study. *Lepr Rev* 2007; 78(2):122-30.
9. Suresh M, Nicholls PG, Das L, Van Brakel WH. Voluntary muscle testing and dynamometry in diagnosis of motor impairment in leprosy: a comparative study within the INFIR Cohort Study. *Lepr Rev* 2008; 79:277-94.
10. Van Brakel WH, Nicholls PG, Wilder-Smith EP, *et al*. Early Diagnosis of Neuropathy in Leprosy—Comparing Diagnostic Tests in a Large Prospective Study (the INFIR Cohort Study). *PLoS Neglected Tropical Diseases* 2008. e212. doi:10.1371/journal.pntd.0000212.
11. Van Brakel W, Nicholls PG, Loretta Das *et al*. The INFIR Cohort Study: investigating prediction, detection and pathogenesis of neuropathy and reactions in leprosy. Methods and baseline results of a cohort of multibacillary leprosy patients in north India. *Lepr Rev* 2005; 76(1): 14-34.
12. DeLisa JA, Hang JL, Baran EM *et al*. Temperature effects on nerve conduction velocities and latencies. Manual of nerve conduction velocity and clinical neurophysiology. *Raven, New York,* 1994:1–21.
13. Dyck PJ, O'Brien PC, Litchey WJ *et al*., et al. Use of percentiles and normal deviates to express nerve conduction and other test abnormalities. *Muscle Nerve* 2001; 24(3): 307-10.
14. Nicholls PG, McKnight J, Das Loretta, Desikan KV, Lockwood DNJ, Wilder-Smith EP, van Brakel WH. Reference values for nerve function assessments among a study population in northern India – I: Vibration Perception Thresholds. *Neurol Asia* 2009; 14(2):129-39.
15. McKnight JM, Nicholls PG, Das Loretta, Desikan KV, Lockwood DNJ, Wilder-Smith EP, van Brakel WH. Reference values for nerve function assessments among a study population in northern India – II: Thermal Sensation Thresholds. *Neurol Asia* 2010; 15(1):27-38.
16. Løseth S, Nebuchennykh M, Stålberg E,, *et al*. Medial plantar nerve conduction studies in healthy controls and diabetics. *Clin Neurophysiol* 2007; 118(5): 1155-61.
17. Awang MS, Abdullah JM, Abdullah MR, *et al*. Nerve conduction study of healthy Asian Malays: The influence of age on median, ulnar, and sural nerves. *Med Sci Monit* 2007; 13(7): CR330-2.
18. Robinson LR, Temkin NR, Fujimoto WY, *et al*. Effect of statistical methodology on normal limits in nerve conduction studies. *Muscle Nerve* 1991; 14(11):1084-90.
19. Arruda APM, Marques W Jr, Foss NT, *et al*. Near nerve potential of sural nerve in leprosy. *Arq Neuropsiquiatr* 2004; 62(3A):571-4.
20. Husain S, Malaviya GN. Early nerve damage in leprosy: an electrophysiological study of ulnar and median nerves in patients with and without clinical neural deficits. *Neurol India* 2007; 55(1):22-6.
21. Soysal A, Atay T, Ozu T, *et al*. Electrophysiological evaluation of peripheral and autonomic involvement in leprosy. *Can J Neurol Sci* 2004; 31(3):357-62.