NORMATIVE DATA FOR MEDIAN AND ULNAR NERVE CONDUCTION AND F-WAVE RESPONSE AMONG HEALTHY INDIVIDUALS

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INTRODUCTION

Electrodiagnostic (EDX) medicine has been in existence since the 1940s. EDX physicians and technologists perform nerve conduction studies (NCS) and needle electromyography to evaluate disorders of the peripheral nervous and musculoskeletal systems. In the past few decades, EDX instrumentation and signal processing have benefitted greatly from technological advancements in computing and electronics[1.] Nerve Conduction Studies (NCS) are useful in evaluating the functions and diseases of the peripheral nerves. NCS help in delineating the extent and the distribution of neural lesions and they distinguish two major categories of peripheral nerve diseases: demyelination and axonal degeneration[2.] Performing NCS on nerves and deciding whether the results fall within an expected range of normal values with a statistical level of precision is fundamental to EDX medicine. With the steady improvement and the standardization of these methods, they have become reliable tests in clinical settings. They are now widely used, not only for the precise localization of lesions but also for the accurate characterization of peripheral nerve functions[3.]

NCS involves the activation of nerves with small, safe electrical impulses over multiple points on the skin of limbs and thereafter measuring the obtained responses. NCS is diagnostically helpful in patients suspected of having almost any kind of peripheral nervous system disorder including disorders of nerve roots, and peripheral nerves[2,3,4]. The technique consists of electrical stimulation of nerves and the recording of the evoked potentials, either from the muscles or from the nerves themselves. Technical factors impart the accurate measurement of NCS parameters for motor and especially sensory nerves with machine settings can contribute to variability in NCS testing. High- and low-frequency filter settings affect both onset latencies and amplitudes and the Specification of these testing parameters are necessary to ensure high-quality study[2,3]. For the upper limb, the median and the ulnar nerves are the most tested nerves in individuals who were carefully screened by using standard distances. In our study, we are looking to establish the normal NCS data for the median and the ulnar nerves in normal healthy individuals aged between 18 – 60 years.

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METHODOLOGY

In total 80 Healthy individuals with normal neurological findings (sensation, stretch reflexes, and muscle strength)" which includes superficial and deep sensory testing) of both sexes, between the age group of 18 and 60 years were included in the study. Purposive sampling was used to divide the group. Data collection was done at the College of Physiotherapy Research Laboratory. A personal/family history of any systemic disorder, any History of neuromuscular disorder, myopathy, nerve injury, Heavy smokers (Smoking Index >200), Alcohol intake with a history of regular drinking of > 100ml/day for more than 4 years, History of upper limb tendon surgeries or nerve grafting involving median and ulnar nerve, Subjects with skin lesions, swelling and trauma to upper limb including fracture that would interfere with Nerve Conduction Study (NCS), Metal implant like pacemaker as it may affect electrical impulses were excluded from the study. Materials used were RMS Salus 2C electromyograph (Recorders and Medicare systems Pvt. Ltd, Chandigarh), Wooden chair, Mat, Pen, marker, conducting medium (gel), Alcohol swab, Cotton, Micropore, Pillow and Measuring tape.

PROCEDURE

Approval was taken from the institutional ethical committee. The selected participants were asked to signed the informed consent form stating their voluntary acceptance to participate in the study. The subjects were thoroughly briefed about the procedure. The considerable gap was given between examinations, to minimize discomforts to subject as well as to enhance their enthusiastic participation.

NERVE CONDUCTION STUDY:

It was performed as per the guidelines of Standardized techniques used to obtain and record action potentials for motor, sensory nerve and f- wave testing. The data was recorded with a RMS Salus 2C electromyograph.

Fig: 4.1
Rms Salus electromyograph with 2 channels

The filters were set at 2-5 kHz for the motor studies and at 20-2kHz for the sensory studies[3].The sweep speed was set at 5ms/division for the motor studies and at 2 ms/division for the sensory studies. A stimulus duration of 50 μs to 1000 μs and a current of 0–100 mA is required for an effective nerve stimulation. The amplitude was set between 20,000 and 100,000 times; electronic impedance was kept below 5kΩ[4-5.] Skin was prepared by scrubbing with disinfectant.

The laboratory temperature was maintained at 25–28°C[6]. An infrared temperature scanner with digital readout was used to record surface skin temperatures. Skin temperatures was recorded at the touch pad of the index finger, mid palm, and antecubital fossa[6,10]. Subjects with extremities temperature of less than 31°

C at any recording site were warmed first with an electric heating device. Each extremity was warmed until all three sites were equal to or greater than 31 degrees C. No recording site was warmer than 35^{o} C[10].

The Subjects were made to sit comfortably on a chair and were asked to avoid unnecessary movement and to remove all the metallic ornaments that they might be wearing. Study was performed in both upper limbs of each subject. Motor and sensory studies were performed on the ulnar and median nerves both proximally and distally along the forearm. 1-cm disc recording electrodes were used for the motor studies and ring recording electrodes were used for the sensory studies. The supramaximal stimuli were delivered in order to get adequate responses i.e. (20 – 30%) "of maximal stimulus".

The data was collected for the following parameters:

For the Motor Nerve:

The Distal Latency (DL), proximal latency (PL)
The Motor Nerve conduction velocity (MNCV) and
The amplitude of the Compound Muscle Action Potential (CMAP)

For the Sensory Nerve:

The Distal latency (DL),
The Sensory Nerve Conduction Velocity (SNCV) and
The Sensory Nerve Action Potential (SNAP)
For F wave study, latency will be calculated.
The sites of stimulation for both the nerves were wrist and the elbow according to standard protocol. Stimulation was delivered using a bipolar handheld stimulator.

MOTOR STUDIES

❖ **For Median nerve:**

- The active electrodes were placed over the **motor point of the abductor pollicis brevis**
- The reference electrode was placed **4 cm distal over the 1st metacarpophalangeal joint.**
- **Distal stimulation** was performed at the wrist (3cm proximal to the distal wrist crease) between the flexor carpi radialis and the Palmaris longus tendon.
- The **Proximal stimulation** for the median nerve was performed medial to the **biceps tendon**, on the volar crease of the brachial arterial pulse.

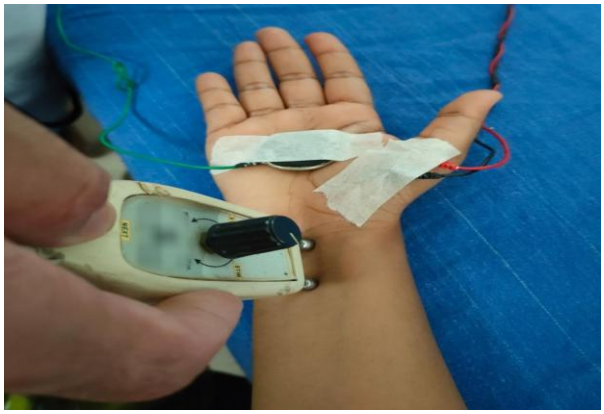

Fig: 4.2: Distal Stimulation at Wrist

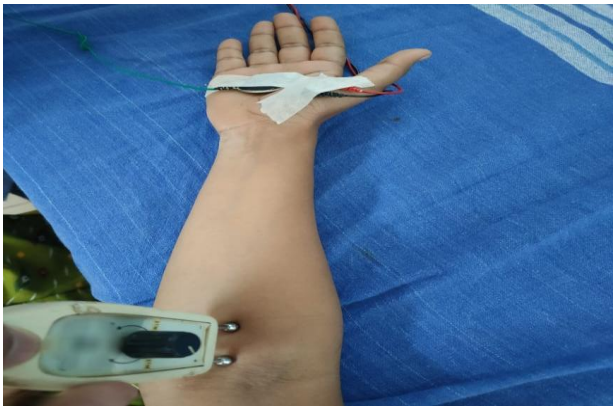

Fig: 4.3: Proximal Stimulation at Elbow

❖ **For Ulnar nerve:**

- The active electrodes were placed over the motor point of the abductor digiti minimi

- The reference electrode was placed at the 5th metacarpophalangeal joint
- The Distal stimulation was given posterior to the flexor carpi ulnaris
- The Proximal stimulation was given 3-4cm distal to the medial epicondyle, with the wrist and the elbow in 90° of flexion. A 90° or 130° flexion during the stimulation and the measurement of the distance is recommended.

Fig: 4.4: Distal Stimulation at Wrist

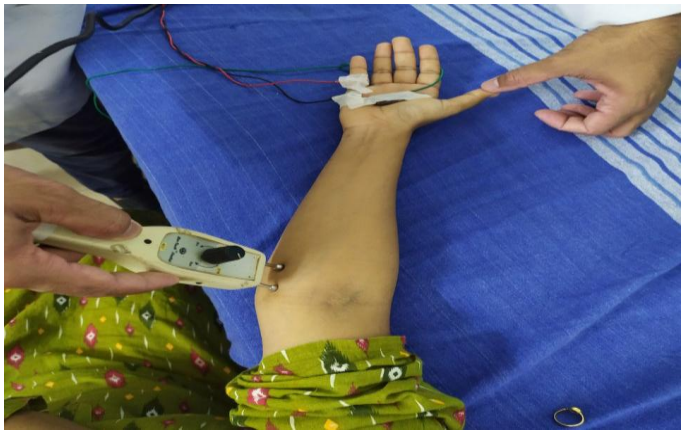

Fig: 4.5: Proximal Stimulation at Elbow

SENSORY STUDIES

- For the median and ulnar nerves were examined antidromically.
- The active ring electrode was placed over the 2nd and 5th digits to record the responses along the median and the ulnar nerves, respectively.
- The reference electrode was placed about 4 cm distal to the active electrode.
- The median nerve stimulation was performed 14 cm proximal to the active electrode and medial to the flexor carpi radialis tendon.
- The ulnar nerve stimulation was performed 10cm proximal to the active electrode and posterior to the flexor carpi ulnaris tendon.

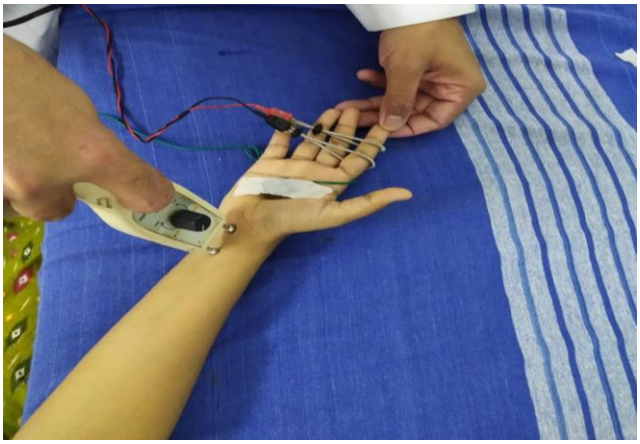

Fig: 4.6: Median Sensory Nerve Stimulation

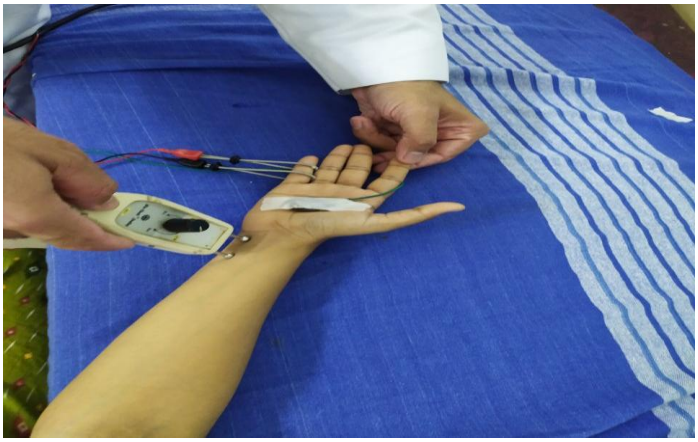

Fig: 4.7: Ulnar Sensory Nerve Stimulation

❖ **The F –wave Study:**

F – wave response was studied with the same electrode placement as for motor nerve conduction study of the median and ulnar nerve but the stimulating electrodes were reversed.

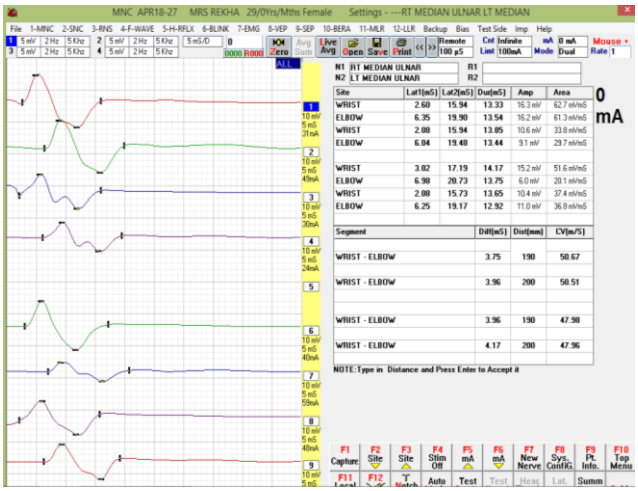

Fig: 4.8: Motor nerve waveform

Fig: 4.9: Sensory nerve waveform

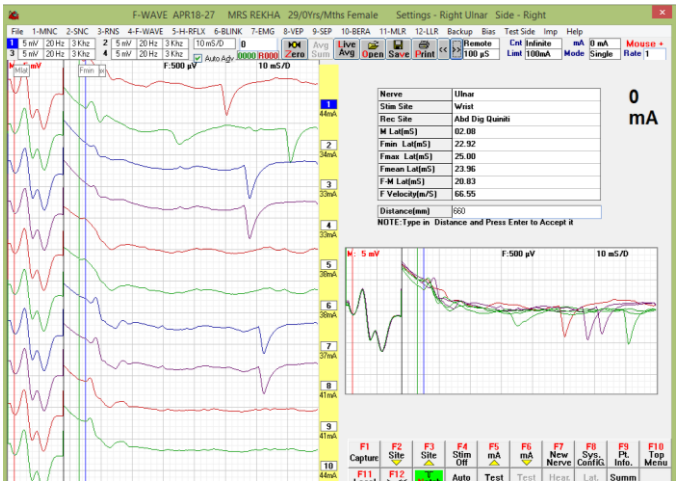

Fig: 5: F-wave(mean) waveform

RESULTS

A total of 80 subjects (35 males, 45 females) with mean age of (41.7) were recruited in our study. The data including demographic and all parameters were recorded on a data collection form and then converted into tabular form (Table 1). The data was entered into software SPSS version 20 in windows. The normality of the data was established by Kolmogorov- smirnov test ($p > 0.05$).

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Table 1: Descriptive statistics for demographic data
(values represented in mean & SD)

Variables	Mean±(SD)
Subjects(N)	80
Age (in years)	41.47± (11.18)
Male(N=35)/Female(N=45)	35(43.7%) / 45(56.2%)

Fig: 5.1: Mean value of Age

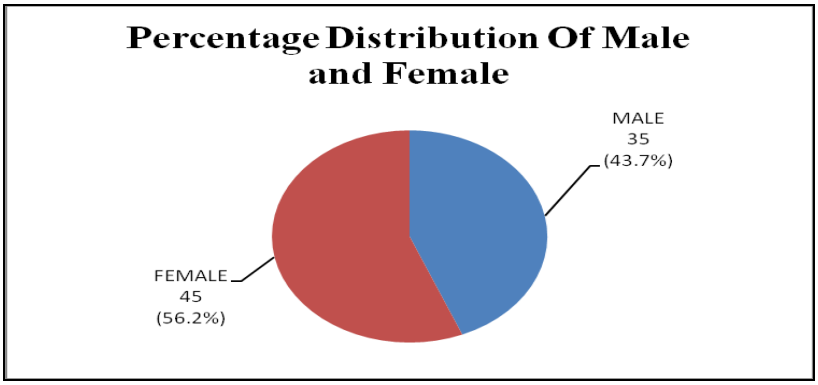

Fig: 5.2: Percentage distribution of males and females

Student's unpaired *t*-test was used to assess the significance of difference between the mean values of median and ulnar nerve parameters (TABLE 2).

Table 2: Mean and Cut-off value for Ulnar nerve

Group	Age
N	80
Mean	41.475
Median	39.500
Std. Deviation	11.184
Range	39.000
Minimum	21.000
Maximum	60.000

Table 2.1: Mean and Cut-off value for Median nerve

Group	Age
N	80
Mean	41.475
Median	39.500
Std. Deviation	11.184
Range	39.000
Minimum	21.000
Maximum	60.000

All the values were expressed in mean and standard deviation for the parameters of the median and the ulnar motor nerves and the sensory nerves of males and females have been summarized in (Table 3). $P < 0.05$ was considered statistically significant. The normal reference range of nerve conduction values was set by the 2.5 and 97.5 percentiles so that the reference ranges contain the central 95% of the distribution.

For right median motor nerve, the values of distal latency and conduction velocity in males were 4.1 ± .91 ms and 49.3 ± 4.8 m/s, respectively, whereas, in females, they were 4.2 ± 1.2 ms and 49.49 ± 5.9 m/s. Similarly, for left median motor nerve, the distal latency and conduction velocity values in males were 4.03 ± .37 ms and 51.09 ± 5.2 m/s, whereas, in females, they were 3.88 ± 1.1 ms and 50.47 ± 4.5 m/s, respectively.

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Table 3: Median Motor Nerve Conduction (RIGHT)

Group		Gender	N	Mean	Std. Deviation	t
	Motor - DL-Right	Male	35	4.167	.912	.199
		Female	45	4.218	1.293	p=0.843 ns
	Motor - PL-Right	Male	35	8.483	1.030	1.832
		Female	45	7.857	1.804	p=0.071
	Motor - NCV-Right	Male	35	49.387	4.825	.086
		Female	45	49.493	5.906	p=0.932 ns
	Motor - CMAP-right	Male	35	8.131	2.748	1.519
		Female	45	9.209	3.424	p=0.133 ns
	Motor - FWL- right	Male	35	28.412	2.305	4.252
		Female	45	26.281	2.160	p<0.001***

Table 3.1: Median Motor Nerve Conduction (LEFT)

Group		Gender	N	Mean	Std. Deviation	t
	Motor - DL-Left	Male	35	4.039	.871	.688
		Female	45	3.880	1.131	p=0.493 ns
	Motor - PL-Left	Male	35	8.203	1.196	2.241
		Female	45	7.523	1.452	p=0.028*
	Motor - NCV-Left	Male	35	51.090	5.277	.564
		Female	45	50.471	4.520	p=0.574 ns
	Motor - CMAP-Left	Male	35	7.469	2.498	1.094
		Female	45	8.122	2.762	p=0.277 NS
	Motor - FWL-Left	Male	35	28.844	3.240	2.178
		Female	45	26.554	5.520	p=0.032*

For right median sensory nerve, the values of latency and velocity in males were 3.19 ± 6.28 ms and 52.81 ± 7.4m/s, respectively, whereas, in females, they were 3.24 ± .89ms and 50.76 ± 6.9m/s. Similarly, for left median sensory nerve, the latency and velocity values in males were 3.11 ± .44ms and 50.62 ± 6.2m/s, respectively, whereas, in females, they were 1.9± .55ms and 51.01 ± 6.1m/s, respectively.

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Table 3.2: Median Sensory Nerve Conduction- RIGHT and LEFT

Group		Gender	N	Mean	Std. Deviation	T
	Sensory-Right-DL	Male	35	3.197	.628	.294
		Female	45	3.249	.891	=0.77ns
	Sensory-Right- NCV	Male	35	52.811	7.425	1.271
		Female	45	50.766	6.914	p=0.208 ns
	Sensory-Right-SNAP	Male	35	47.287	5.537	.364
		Female	45	46.852	5.119	p=0.717 ns
	Sensory-Left-DL	Male	35	3.111	.447	1.073
		Female	45	2.987	.555	p=0.287 ns
	Sensory-Left-NCV	Male	35	50.620	6.258	.279
		Female	45	51.011	6.187	p=0.781 ns
	Sensory-Left-SNAP	Male	35	47.741	5.539	1.475
		Female	45	45.408	7.973	p=0.144 ns

For right ulnar motor nerve, the values of distal latency and conduction velocity in males were 2.7 ± .44 ms and 50.64 ± 6.4 m/s, respectively, whereas, in females, they were 2.4 ± .43ms and 49.49 ± 5.9 m/s. Similarly, for left ulnar motor nerve, the distal latency and conduction velocity values in males were 2.8 ± .65 ms and 48.45 ± 9.2 m/s, whereas, in females, they were 2.3 ± .39 ms and 52.90 ± 5.8 m/s, respectively.

Table 3.3: Ulnar Motor Nerve Conduction (RIGHT)

Group		Gender	N	Mean	Std. Deviation	T
	Motor - DL-Right	Male	35	2.708	.444	2.244
		Female	45	2.487	.434	p=0.028*
	Motor - PL-Right	Male	35	7.101	.828	5.232
		Female	45	6.320	.498	p<0.001***
	Motor - NCV-Right	Male	35	50.642	6.467	1.336
		Female	45	52.678	6.981	p=0.185 ns
	Motor - CMAP-right	Male	35	7.374	1.669	1.473
		Female	45	6.902	1.197	p=0.145 ns
	Motor - FWL- right	Male	35	27.572	2.173	8.068
		Female	45	24.515	1.167	p<0.001***

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Table 3.4: Ulnar Motor Nerve Conduction (LEFT)

Group		Gender	N	Mean	Std. Deviation	T
	Motor - DL-Left	Male	35	2.808	.657	4.153
		Female	45	2.318	.391	p<0.001***
	Motor - PL-Left	Male	35	7.209	.915	5.232
		Female	45	6.116	.536	p<0.001***
	Motor - NCV-Left	Male	35	48.459	9.277	2.620
		Female	45	52.900	5.812	p=0.011*
	Motor - CMAP-Left	Male	35	6.900	1.328	.365
		Female	45	7.018	1.504	p=0.716 NS
	Motor - FWL-Left	Male	35	27.968	2.040	8.342
		Female	45	24.797	1.352	p<0.001***

For the right ulnar sensory nerve, the values of latency and velocity in males were 2.5 ± .27 m/s and 59.45 ± 5.8m/s, respectively, whereas, in females, they were 2.26 ± .17m/s and 62.98 ± 4.9m/s. Similarly, for the left ulnar sensory nerve, the latency, and velocity values in males were 3.11 ± .44m/s and 50.62 ± 6.2m/s, respectively, whereas, in females, they were 2.04 ± .18m/s and 70.13 ± 6.2m/s, respectively.

Table 3.5: Ulnar Sensory Nerve Conduction – RIGHT and LEFT

Group		Gender	N	Mean	Std. Deviation	T
	Sensory-Right-DL	Male	35	2.533	.278	5.157
		Female	45	2.269	.178	p<0.001***
	Sensory-Right- NCV	Male	35	59.450	5.849	2.941
		Female	45	62.987	4.903	p=0.004**
	Sensory-Right-SNAP	Male	35	48.296	4.379	.541
		Female	45	49.123	8.176	p=0.59 ns
	Sensory-Left-DL	Male	35	2.322	.326	4.838
		Female	45	2.043	.184	p<0.001***
	Sensory-Left-NCV	Male	35	65.257	8.045	3.045
		Female	45	70.139	6.299	p=0.003 **
	Sensory-Left-SNAP	Male	35	49.577	5.628	1.505
		Female	45	47.115	8.298	p=0.136 ns

There was no statistically significant difference in the median nerve motor parameters of both sides in distal latency (DL) but there was a statistically significant difference in F-wave latencies (FWL) and for ulnar nerve motor parameters of both sides (DL and F-wave latencies).

There was no statistically significant difference in the distal sensory latency and conduction velocity of the median sensory nerve on both sides whereas for the ulnar sensory nerve it was highly significant for both

sides. The amplitude of the sensory action potential for both nerves was found to be less in females than in males. It seemed to be significantly influenced by gender.

By using Pearson's correlation coefficient (*r*) between age and nerve conduction parameters (Table 4) it was found there was a highly significant positive correlation of median motor nerve parameters of DL (.009), F-WAVE(.001) (right side), and PL(.009), AND F-WAVE(.010)(left side) and significant correlation for conduction velocity of both sides right side(.035) and left side(.028). Median sensory nerve showed a significant positive correlation for only right-side latency (.029) and SNAP (.042). For the ulnar motor nerve, there was only a highly significant positive correlation of CMAP (.005) on (the left side). The ulnar sensory nerve showed a positive correlation for right (.027) and left (.022) side conduction velocity (SNCV).

Table 4: Correlation of Age with NCV (MOTOR) parameters

Group			Motor - DL-Right	Motor - PL-Right	Motor - NCV-Right	Motor - CMAP-Right	Motor - FWL-Right	Motor - DL-Left	Motor - PL-Left	Motor - NCV-Left	Motor - CMAP-Left	Motor - FWL-Left
Ulnar nerve conduction	Age	R	.005	.094	-.167	-.094	.212	.140	.073	-.018	-.311	.097
		P	.964	.409	.139	.409	.059	.217	.517	.875	.005**	.393
		N	80	80	80	80	80	80	80	80	80	80
Median nerve conduction	Age	R	.290	.183	-.236	-.198	.365	.184	.289	-.246	-.012	.285
		P	.009**	.104	.035*	.078	.001***	.101	.009**	.028*	.913	.010**
		N	80	80	80	80	80	80	80	80	80	80

Table 4.1: Correlation of Age with NCV (SENSORY) parameters

Group			Sensory-Right-DL	Sensory-Right- NCV	Sensory-Right-SNAP	Sensory-Left-DL	Sensory-Left-NCV	Sensory-Left-SNAP
Ulnar nerve conduction	Age	r	.153	-.247	.110	.195	-.256	-.158
		p	.174	.027*	.329	.083	.022*	.161
		N	80	80	80	80	80	80
Median nerve conduction	Age	r	.245	-.109	-.227	.172	-.195	.076
		p	.029*	.335	.042*	.126	.083	.505
		N	80	80	80	80	80	80

DISCUSSION

Nerve conduction studies (NCSs) are the most commonly used electrodiagnostic tests to determine the conduction in motor and sensory nerves [1] NCS involves activation of nerves with small, safe electrical impulses over multiple points on the skin of limbs and thereafter measuring the obtained responses[2] The median nerve study is one of the most commonly performed NCS tests. It has been extensively used in research field as well as in clinical practice. NCS 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. For NCS, reference values should be established from the local population because previous studies have shown differences in NCS function related to ethnicity and demographic factors. Therefore, considering these factors, this study examined the nerve conduction parameters of the two commonly tested nerves: the median and the ulnar nerves, in both the upper limbs of a healthy adult population to provide the normative and the reference values in our research lab. 80 carefully screened, healthy individuals of either sex (35 males and 45 females), were selected for this study with mean age of the 41.47±11.18 with range of 21years to 60 years. Study was performed in both upper limbs of each subject. Motor and sensory studies were performed on the ulnar and median nerves both proximally and distally along the forearm. There was no statistically significant difference in the median nerve motor parameters of both sides in distal latency (DL) ($p>0.05$) but there was a statistically significant difference in F-wave mean latencies (FWL) ($p<0.05$) and for ulnar nerve motor parameters of both sides DL and F-wave mean latencies(FWL) ($p<0.05$).

There was no statistically significant difference in the distal sensory latency DL ($p>0.05$) and conduction velocity (SNCV) of the median sensory nerve of both sides ($p>0.05$) whereas for the ulnar sensory nerve it was highly significant, DL ($p<0.05$) and SNCV ($p<0.05$) for both sides. The results of this study for the motor nerve conduction parameters of the ulnar and the median nerves were in accordance with those of Hennessey et al[8]. There was no influence of gender on the nerve conduction velocities and the distal latencies, but the effect of gender was only significant and it affected the sensory nerve potential amplitude (SNAP) and compound muscle action potential (CMAP). In this study, the amplitude of the sensory action potential for both nerves was found to be less in females than in males except for the right ulnar. The CMAP was found to be more in females than in males except for the left ulnar. It seemed to be significantly influenced by gender. The present study was not in accordance with Thakur et al. which showed that gender had definite effects on the amplitude, duration, and latency of the motor and the sensory nerves and showed males had a higher CMAP amplitude and longer latencies and durations as compared to females. The SNAP latencies and durations were longer in males, whereas the amplitude was higher in females[12]. There may be a number of factors that may have affected the CMAP and SNAP recorded. These include the distance between the recording and stimulating electrodes. Increased distance causes physiologic dispersion and loss of synchrony among the individual nerve fiber action potentials, producing a small amplitude. Additionally, technical problems can interfere with the recording of sensory nerve conduction studies, including limb edema, thickened skin, gross obesity, and muscle artifacts caused by either inadequate relaxation or simultaneously evoked compound muscle action potentials[11].

Our study results correlated well with the study by Palve SS et.al, who in their study found, there was a significant negative correlation between age and both median motor and sensory nerves with r value. In this study, there was a highly significant positive correlation of median motor nerve parameters of DL and F-WAVE ($p<0.05$) of the right side and PL and F-WAVE ($p<0.05$) of left side and a significant negative correlation for conduction velocity (CV) of both side ($p>0.05$) with age. Median sensory nerve showed a significant negative correlation for only right-side latency and SNAP ($p>0.05$) with age. For the ulnar motor nerve, there was only a highly significant negative correlation of CMAP ($p<0.05$) of (left side) with age. The ulnar sensory nerve showed a negative correlation but was significant for both sides of conduction velocity (SNCV) ($p>0.05$) with age. The reason for this may be decreased excitability and conduction

velocity of the nerves which can be explained by the hypothesis that there is an increase in oxygen free radicals with aging which tend to damage the enzyme systems in the mitochondria which lead to a decrease in ATP production resulting in slowing of muscle contraction, alteration in muscle metabolism, and neuromuscular junction[6].

The values for the nerves which were tested in this study, agreed with those of most of the other researchers, while a few nerve parameters showed considerable differences. This difference between the results of the present study and the data which has been published in the literature could be due to a variety of causes. First, the age difference between the participants included in the present and previous studies may have contributed to the above-noted differences in the results. The second cause can be due to the diversity of the methods and techniques (the studies differed in the maneuvering setting and the recording of the electrical responses, and the equipment which was used). lastly, the type of electrodes that were used could also be the source of this variation. Besides, different studies were done on different ethnic groups.

Hence the consequent methodology and geographical differences as well as the variations in the lifestyle, dietary, and morphological characteristics of study participants might also have influenced the study results.

STUDY LIMITATIONS

- A major limitation of our study was the non-inclusion of height, weight, and BMI, thus limiting the benefit of this study.
- Another limitation of this study was the non-inclusion of a larger sample size, thus limiting the benefit to a specific section of society.

CONCLUSION

In conclusion, the normative conduction parameter of a commonly tested peripheral motor nerve in the upper limb was established in our Laboratory of the Department.

Our values will prove useful in the accurate interpretation of median nerve abnormalities in young adults from this part of India, by reducing the incidence of false positives/negatives. This study could be used for the evaluation of peripheral nerve injury. The diagnostic conclusion could also be made from the nerve conduction study data.

The study created preliminary data on this population in a limited sample. Our present study has many similarities as the overall mean motor and sensory nerve conduction parameters for the median and the ulnar nerves correlated favourably with the literature data and some dissimilarity with the reported NCS variable (i.e., CMAP,SNAP). Gender has been shown to have a significant effect on the sensory potential amplitudes for the median and the ulnar nerves. This data may be used as a preliminary working reference while reporting clinical NCS findings.

This study is the only study of this region of india to give cutoff values and percentiles by following NDTF proposed set of quality criteria to define the important methodological issues required of studies that investigate nerve conduction normative values. So in this way, this study holds a strong strength.

FUTURE RECOMMENDATION

- A major limitation of our study was the limited sample size so, a study with a larger sample size can be considered so as to widen the power of the study and better generalizability.
- Clinical research should continue to assess the normative data in other peripheral nerves (e.g., common peroneal, sural, tibial).
- Furthermore, more such studies need to be conducted by other authors so as to generate reference data that is specific to their local populace.

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