Nerve Conduction Studies in Healthy Iraqis: Normative Data

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Abstract

Background: Nerve conduction studies as part of the peripheral neurophysiologic examination are an extension of the clinical history and examination. They can be extremely useful both in localizing lesions and determining the pathological processes.

Objective: To establish the normal electrophysiological data for the facial nerve and commonly tested nerves of the upper and lower limbs in healthy Iraqis and to compare with those data published in the literature.

Methods: Nerve conduction studies were performed in the upper and lower limbs of 11,437 carefully screened healthy individuals between the ages of 2 months and 89 years using a standardized technique.

Results: The data were separately analyzed for different age groups. In the age group less than 10 years, the sensory and motor nerve conduction velocities were progressively increasing with increasing age until adult values were reached. Later, in the adulthood, the conduction velocity of all tested nerves decreased with age and this is pronounced in both lower and upper limbs.

Conclusion: Normative conduction parameters of the facial nerve and peripheral nerves in the upper and lower limbs were established for the EMG laboratory in Iraq. The overall mean sensory and motor nerve conduction parameters for the tested nerves compared favorably with the existing literature data.

Keywords: Upper limbs, Lower limbs, Nerves, Conduction Velocity, Iraqis

IRAQI J MED SCI, 2009; VOL.7 (2): 75-92

Introduction

Nerve conduction studies (NCS) afford data on peripheral nervous system function which may be used to provide diagnosis, description of disease state (old/new; dynamic/static pathophysiology), longitudinal monitoring of disease by using multiple studies, and advice on prognosis and management based on the test results and the disease detected (1-6).

Another type of NCS is referred to as late response (F-wave testing) and is usually performed on nerves more proximal to the spine.

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Received: 26th March 2009, Accepted:1st June 2009.

These segments include the first several centimeters of a compound nerve emerging from the spinal cord or brainstem.They are helpful in diagnosing conditions of radiculopathies, plexopathies, polyneuropathies, and proximal mononeuropathies (6). Late response studies are additional studies complementary to nerve conduction velocity and are performed during the same patient evaluation (1).

Age-matched "Normal" values for NCS parameters are either derived from studies of groups of neurologically normal subjects or culled from the literature (7). Many studies have been published from the Western countries regarding normative data for the nerves of the upper and lower limbs (8-13). Unfortunately, in the Middle East, such studies are limited; in the best conditions, the number does not exceed few hundreds (14-17).

For the last few decades, electrophysiology laboratories have been applying standard values used by the US, Canada and Europe to diagnose different neurological problems.

This study is therefore intended to obtain a set of data from a large scale of healthy Iraqis in order to establish reference values for the local EMG laboratory and to compare Iraqi values with worldwide published data.

There are a number of physical parameters that require correction or allowance for when establishing normative electrophysiological data. The most important is temperature i.e., the motor nerve conduction velocity (MNCV) is reduced by approximately 1 m/s per °C temperature fall. Some measures of conduction require correction for limb length or height. Finally nerve conduction data alter with age. The motor conduction slows by 0.4–1.7 m/s per decade after 20 years and the sensory by 2–4 m/s [7].

This paper provides normative electrophysiological data for the facial, median, ulnar, radial, musculocuatneous, axillary, femoral, common peroneal, and tibial nerves in healthy individuals at different age groups using standard distances and temperature control.

Subjects and Methods

Eleven thousands and four hundred thirty seven healthy individuals, aged 2 months to 89 years (36.39±15.36), were included in this cross-sectional study. They comprised 6,325 women with an average age of (38.05±13.79 years) and 5,112 men with an average age of (34.11±17.04 years).

Two thousands and four hundred forty four subjects were specifically recruited as normal. The rest were felt normal, so an informed consent was taken from them or their parents or relatives to do multiple nerve conductions on the normal limb(s).

The data were collected from individuals attending the EMG unit at Al-Kadhimiya Teaching Hospital, Baghdad-Iraq for neurophysiologic assessment during a 14-year period (1992-2006). All individuals were screened for inclusion criteria that comprised normal neurological physical examination, normal laboratory findings regarding serum sugar, electrolytes and renal function. A standardized questionnaire was used to exclude those with a history of systemic or neuromuscular diseases.

The following individuals were excluded: those with a history of alcohol abuse or medications that might affect the results, and those with a history of diabetes, hypothyroidism and systemic diseases. None of the individuals were taking any medication at the time of conducting the EMG study.

A basic neurological examination was performed to assess muscle power, stretch reflexes and sensations both superficial and deep. Room temperature was maintained at 25 °C. The EMG study was performed with the subject lying comfortably in the supine position. A standardized technique was used to obtain and record action potentials for motor and sensory functions [18].

A 4-channel electromyography machine (Dantec, Denmark) was set as follows: for motor nerve conduction, the low cut filter was 2–5 Hz and the high cut was 10 KHz. For sensory nerve conduction, low cut: 5–10 Hz, high cut: 2–3 KHz; the amplification between 20,000 and 100,000 times; electrode impedance was kept below 5 kΩ; sweep speed for sensory nerve conduction: 1–2 ms/ division while for motor nerve conduction: 2–5 ms/ division; and a stimulus duration of 50 μs to 1000 μs and current 0–100 mA are required for effective nerve stimulation. Supramaximal stimulation (10%–30% more than the current required for maximal action potential) was used.

Data were collected for the following parameters: distal latency measured from the onset of action potential, conduction velocity, and amplitude of compound muscle action potential (CMAPA) and sensory nerve action potential (SNAPA) were measured from positive peak to the negative peak.

The following nerves were evaluated: for motor nerve conduction velocity– facial, median, ulnar, radial, axillary, musculocutaneous, tibial, common peroneal, and femoral nerves; for sensory nerve conduction velocity (SNCV) – median, ulnar, radial, musculocutaneous, tibial, and superficial peroneal nerves were evaluated.

The motor nerves were examined orthodromically and stimulated with bipolar surface stimulating electrode (Dantec 13L36) at two points along its course. The action potential was recorded with a concentric needle electrode (Dantec 13L50) placed close to the motor point of the muscle. A ground electrode (Dantec 13S93) was placed between the stimulating and recording electrodes. The MNCV was calculated using the distance between points of two stimulations by latency of that segment.

Stimulation of facial nerve was achieved at a point just below the ear and anterior to the mastoid process. Its motor response was recorded from orbicularis oris muscle. Distal median and ulnar stimulations were performed 8 cm proximal to the needle electrode. The site was medial to flexor carpi radialis tendon for the median nerve while posterior to flexor carpi ulnaris tendon for the ulnar nerve. Proximal median nerve stimulation was performed medial to biceps brachii tendon at the elbow crease. For ulnar nerve, proximal stimulation was just distal to the medial epicondyle of the humerus with the elbow in 70° flexion. Recordings of the muscle response for the median and ulnar nerves were done from abductor pollicis brevis and abductor digiti minimi muscles, respectively.

The radial nerve was stimulated distally at the lateral edge of extensor carpi ulnaris muscle, 8 to 10 cm proximal to the styloid process of the ulna and the recording from extensor indicis muscle. Proximally, radial nerve was stimulated between brachioradialis and the tendon of biceps brachii 6 cm proximal to the lateral epicondyle of the humerus. The musculocutaneous and axillary nerves were stimulated at the posterior cervical triangle 3 to 6 cm above the clavicle just behind sternocleidomastoid muscle. Muscle action potentials were recorded from biceps brachii and deltoid muscles, respectively.

For deep peroneal motor nerve conduction evaluation, the recordings were obtained from extensor digitorum brevis. The stimulation was given at the ankle distally and 2 cm distal to the fibular neck (below knee) proximally. Motor conduction study of the tibial nerve recorded the muscle response from abductor hallucis muscle after stimulation at the popliteal fossa and at the ankle posterior to the medial malleolus. The femoral nerve was stimulated below the inguinal ligament and lateral to the femoral artery. Motor conduction was recorded from rectus femoris muscle 14 and 30 cm distal to the point of stimulation.

Sensory nerve conduction was measured antidromically. The SNCV was measured by stimulating at a single site. The sensory conduction velocity was calculated by dividing the distance between the stimulating and the recording sites by latency.

The active ring electrode (Dantec 13L69) was placed over the 1st, 2nd and 5th digit to record responses along the radial, median and ulnar nerves, respectively. The reference electrode was placed about 4 cm distal to the active electrode. Median nerve stimulation was performed at 13 cm proximal to the active electrode and medial to flexor carpi radialis tendon. For the ulnar nerve, stimulation was performed 10 cm proximal to the active electrode and posterior to the flexor carpi ulnaris tendon. Radial nerve stimulation was performed 10 cm proximal to the active electrode along the lateral border of the radius.

The musculocutaneous was stimulated between the tendon of biceps brachii medially and brachioradialis laterally. The Self adhesive disposable surface recording electrode (Dantec C13L20) was placed 12 cm distal to the point of stimulation over the course of the nerve in the forearm and along the straight line from the stimulus point to the radial artery at the wrist.

Sensory conduction studies of the tibial nerve (medial planter nerve) from the first toe with ring electrodes and antidromic stimulation at the ankle (at the same site that elicits the motor response). The superficial peroneal nerve was stimulated against the anterior edge of the fibulae 12 cm proximal to the active surface electrode located just medial to the lateral malleolus at the ankle.

Because of difference in length of the upper and lower limbs among individuals and thus differences in length of the reflex arc, the disparity was taken into account. In order to quantify individual differences, the distance between the anterior superior iliac spine and the lateral malleolus for the lower limbs and the distance between the seventh cervical spinous process and the wrist for the upper limbs were considered.

Data were processed using the Statistical Package for Social Sciences (SPSS). Descriptive statistics for continuous variables included the mean and the standard deviation. Correlation coefficient (r) was used (P value < 0.05) to assess the relation between the age of the subjects and the conduction velocity of the nerves studied.

Results

Data were separately analyzed for each age group. In the age group less than 10 years, the SNCV and MNCV of median, ulnar, radial, tibial, and common peroneal nerves progressively increased (positively correlated) with increasing age until they reached adult values. Late in the adulthood (age groups 60 years and above), the conduction velocity of all the nerves tested decreased with age (negatively correlated).

The mean and standard deviation for the tested nerves are summarized in tables 1 through 9. Tables 10 through 19 show a comparison between the results of the present study and those reported by others worldwide.

Discussion

This study examined nerve conduction parameters of multiple nerves in the upper and lower limbs of a healthy sample in Iraq under standardized conditions. The aim is to provide normative and reference values for Iraqi EMG labs. A comparison was made between the results obtained in this study and other published data with a special emphasis on studies that used standardized techniques and recorded the age of the subjects [8, 9, 13, 14, 16, 17, 19-39].

Age has been widely accepted to have an influence on nerve conduction velocity. Consequently, many laboratories have produced normative nerve conduction velocity values which are divided according to age groups. Many investigators have attempted to study the association between aging and nerve velocities, both motor and sensory[40-44]. In this study, the statistically significant increment or decrement of NCV with age collaborates with the findings of other researchers [45-49].

The motor parameters of the facial nerve as recorded in this study generally coincide with the results of other researchers [19-21]. The motor latency of axillary nerve was in close proximity to that reported by Kraft [22]. The SNCV values of musculocutaneous were close to the values reported by other workers [23-25], while the SL and SNAPA values were less than the reported values by Kraft [22] and Spindler and Felsenthal [25] (table 10).

For the femoral nerve motor latency, our data were in close proximity to those reported by Uludag et al. [15] and Gassel [26]; whereas the DML and MNCV are far less than that reported by the latter worker and Johnson et al. [27] (table 10).

For the median sensory parameters (table 11), the SNCV is less than that reported by Hennessey et al. [8] and Karagoz et al. [28] but similar to the results of Shehab [14], Awang et al. [16] and Kimura [18]. Moreover, the recorded SNAPA is less than that reported by Shehab [14] and higher than that of Hennessey et al. [8], Kimura [18], and Karagoz et al. [28].

On the other hand, the results of the motor parameters were more favorable with the almost similar MNCV results of others [8, 14, 16, 18, 28]. The median nerve CMAPA in this study was similar to that of Hennessey et al. [8] and Shehab [14], but higher than that of Kimura [18] and Karagoz et al. [28].

The data of ulnar SNCV were in agreement with the findings of Shehab [14] and Kimura [18] but less than those reported by others [16, 27]. Ulnar SNAPA was similar to the results of Shehab [14] but rather higher than that of other researchers [18, 28]. The motor data of ulnar nerve showed a good similarity with those reported by Shehab [14], Kimura [18], Karagoz et al. [28], and Buschbacher [29]. Apart from this, the MNCV was higher as compared to that of Awang et al. [16] and the CMAPA was also higher in comparison to that of Shehab [14] and Kimura [18] (table 11).

Concerning the results of radial nerve (table 11), the SNCV, MNCV, and CMAPA values were in close proximity to the findings of Shehab [14], Jebsen [30], and Trojaborg and Sinrup [31]. On the other hand, the SNAPA was higher than that reported by Falco et al. [9], Johnson et al. [13], Shehab [14], and Trojaborg and Sinrup [31].

In table 12, it can be observed that the sensory and motor CV of the tibial nerve was favorable with the results of Kimura [18], Buschbacher [32], Budak [33], and Antunes et al. [34]. However, the SNAPA and CMAPA were higher than that reported by Antunes et al. [34] and Kimura [18], respectively. On the contrary, the CMAPA was less than that reported by Buschbacher [32] and Antunes et al. [34].

Regarding the data of common peroneal nerve, SNAPA, MCNV, and CMAPA values were similar to those encountered by Kimura [18], Karagoz et al. [28], DiBenedetto [35], Buschbacher [36]. However, the SNCV and MNCV were slightly lower than that reported by DiBenedetto [35] and Karagoz et al. [28], respectively (table 12).

As presented in table 13, the values of F-wave parameter recorded from the median, ulnar, tibial, and common peroneal nerves were in accordance with those reported by Kimura [18], Alavian-Ghavanni and Haghparah [17], Budak [33], Buschbacher [37-39].

To sum up, the values for most of the nerves tested agree with most of the other researches while few nerve parameters were showing a considerable departure. The difference between the results of the present study and the data published in the literature could be attributed to variety of causes.

Firstly, the difference in the distance between the stimulating and recording electrodes and the muscles tested which inflicted well on the lower values of median and ulnar SNCV and femoral MNCV reported in this study i.e., the latter nerve was tested from the rectus femoris muscle while it was studied by Johnson et al [27] from vastus medialis muscle. .

Secondly; the age of the subjects studied. Most studies used middle aged subjects (between 20 years and late fifties) [14, 16, 29, 32, 36-39] while we extended the study to include younger groups (those below 1 year) and older groups (above 80 years). Consequently, the effect of age on conduction velocity was more clearly evident in the present study (tables 1 through 9).

Thirdly; number of the subjects examined. In the best conditions of other studies, the number of examined subjects does not exceed few hundred [14-17]. This number is far less than the number of subjects included in the present study. It is doubtless that increasing the number of subjects examined will smooth the data and reduces the bias in the statistics.

Fourthly; the diversity of the methods and techniques (studies differ in maneuvering, setting, recording the electrical response, and equipment used). The SNAPA for the nerves tested in this study was higher than the data published in the literature because we measured the amplitude from the peak of the negative potential to the peak of positive potential rather than from the baseline to the peak of the negative potential as adopted by others [8, 9, 13, 14, 18, 28, 31, 34, 35].

The type of electrode used could also be a source of variation. Surface electrodes as used by Shehab [14], Awang et al. [16], and Buschbacher [29, 32, 36-39] are designed to give information about the whole muscle stimulated. Such electrodes will record the time taken for the fastest axons to conduct an impulse to the muscle.

In the present study where a needle electrode was used, accurate conduction time information were obtained even with simultaneous activation of many nerves[22]; nevertheless, needle electrodes record from only a small area of muscle or nerve, which necessarily provide more complex information and making numerical analysis difficult [7]. Yet, NCS are routinely performed with needle electromyogram rather than surface electrodes. The routine use of needle electrodes enables the examiner to determine the site and extent of peripheral nerve pathology [2-6]. Providing standardized data using a needle electrode is more essential from the practical point of view.

Finally; the ethnic group studied. Some studies were done on Caucasian subjects, others on Asian; however, none of the studies examined the effect of age on NCV among Caucasian populations living in different geographical areas. Similarly, there is no study comparing the effect of aging on NCV between Iraqis and Asian.

At present it is difficult to attribute the differences to a single factor. On the other hand, the diversity could have resulted for variables that were not yet considered by workers such as body built and climatic dwelling conditions. Further clarification will wait studying the effect of factors such as body mass index on NCV.

Conclusion

Normative conduction parameters of facial and peripheral nerves in the upper and lower limbs were established for our EMG lab in Iraq. The overall mean sensory and motor nerve conduction parameters for the tested nerves compared favorably with the existing literature data.

Acknowledgement

I acknowledge with thanks Dr. RG Ossi for his valuable neurological examination and assistant professor Dr. Akram A. Jaafar for revision of the manuscript.

Table 1: Facial Nerve Parameters in Different Age Groups

Age Group (years)	**DML (msec)**	**MNCV (m/sec)**	**CMAPA (mV)**
1-10 (n = 176)	3.03±0.1	24.88±1.78	1.4±1.8
11-20 (n = 203)	2.97±0.3	31.02±1.8	1.8±1.2
21-30 (n = 288)	3.06±0.19	30.17±2.11	2.1±1.9
31-40 (n = 356)	3.18±0.22	33.3±3.19	2.8±2.1
41-50 (n = 477)	3.3±0.47	31.44±3	3.0±2.1
51-60 (n = 291)	3.27±0.71	29.4±4.06	3.1±2.4
61-70 (n = 178)	4.1±0.91	28.9±5.33	2.6±1.9

The values are presented as mean±SD, n = number, DML = distal motor latency measured from the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak.

Table 2: Median Nerve Parameters in Different Age Groups

Age Group (years)	SL (msec)	SNCV (m/sec)	SNAPA (μV)	DML (msec)	MNCV (m/sec)	CMAPA (mV)	F-wave (msec)
< 1 n = 442	1.37±0.15 (1.2-1.5)	35.37±6.65 (30.0-42.8)	36.1±8.4 (13.6-54.8)	2.83±0.4 (2.4-3.2)	46.83±2.78 (44.8-50.0)	9.12±4.32 (5.88-15.2)	15.97±1.56 (14.5-17.6)
1-10 n = 678	1.53±0.25 (1.2-2.4)	52.8±4.71 (42.3-59.1	57.3±15.2 (35.2-73)	2.61±0.59 (1.8-3.6)	56.35±5.03 (44.0-61.5)	13±7.75 (8.8-24.6)	21.7±3.80 (17.2-28.8)
11-20 n = 716	1.84±0.23 (1.5-2.5)	53.35±3.75 (45.0-61.0)	57.8±17.2 (20-67)	3.28±0.47 (2.0-4.2)	58.73±5.21 (48.9-68.2)	13.98±3.5 (9-17.1)	26.89±2.36 (20.6-32.0)
21-30 n = 1110	1.87±0.18 (1.5-2.5)	52.98±3.83 (43.5-66.6)	61.1±29.57 (14-140)	3.34±0.45 (2.3-4.8)	59.72±4.39 (47.7-68.5)	15.83±5.57 (7.7-30)	26.67±2.31 (21.3-35.4)
31-40 n = 1301	1.94±0.2 (1.5-2.6)	52.09±3.87 (42.8-62.5)	51.79±19.8 (22-92)	3.35±0.43 (2.3-4.7)	59.79±4.98 (50.0-80.0)	15.23±5.1 (6.6-27.2)	26.86±2.12 (21.6-34.7)
41-50 n = 1224	1.99±0.2 (1.6-2.6)	50.44±3.91 (40.8-59.3)	38.27±12.7 (20-64)	3.47±0.49 (2.1-5.2)	58.3±4.72 (47.8-69.7)	14.29±4.77 (5.2-25)	27.57±2.54 (21.5-34.2)
51-60 n = 879	2.01±0.26 (1.6-2.7)	51.06±4.44 (40.0-63.8)	37.88±13.5 (16.4-59.2)	3.51±0.54 (2.4-4.6)	57.15±4.16 (50.0-64.8)	14.39±4.75 (5.3-22.5)	28.41±2.82 (22.8-36.7)
61-70 n = 536	2.1±0.22 (1.8-2.7)	49.42±2.98 (43.4-55.5)	37.18±17.1 (15.6-70)	3.50±0.47 (2.5-4.5)	56.79±4.50 (46.0-65.7)	11.76±2.47 (7.4-16.3)	29.39±2.15 (26.2-34.3)
71-80 n = 321	2.27±0.23 (2.0-2.4)	43.17±2.15 (43.7-45.8)	22.91±8.4 (7.63-43.2)	4.63±0.60 (4.0-5.2)	52.4±2.26 (49.9-54.3)	8.99±5.66 (4.8-15.7)	33.27±0.51 (32.7-33.7)

The values are presented as mean±SD, n = number, SL = sensory latency; SNCV = sensory nerve conduction velocity; SNAPA = sensory nerve action potential amplitude, DML = distal motor latency measured from the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak. The values between brackets represent the range.

Table 3: Ulnar Nerve Parameters in Different Age Groups

Age Group (years)	SL (msec)	SNCV (m/sec)	SNAPA (μV)	DML (msec)	MNCV (m/sec)	CMAPA (mV)	F-wave (msec)
< 1 n = 331	1.37±0.15 (1.2-1.5)	35.37±6.65 (30.0-42.8)	38.81±11.4 (16.56-49.7)	2.83±0.4 (2.4-3.2)	46.83±2.78 (44.8-50.0)	10.1±5.52 (6.98-14.3)	16.81±1.13 (14.8-18.1)
1-10 n = 642	1.73±0.29 (1.3-2.6)	48.92±4.50 (40.4-55.8)	49.41±19.85 (19.6-87.3)	2.36±0.47 (1.7-3.3)	55.06±3.89 (46.4-61.3)	12.68±9.8 (5.5-27.2)	21.43±2.6 (14.9-25.1)
11-20 n = 619	1.94±0.18 (1.6-2.5)	54.18±3.80 (44.0-62.5)	58.58±10.11 (48-70.5)	2.53±0.64 (1.8-4.6)	63.07±5.71 (50.0-74.2)	12.61±4.44 (4.88-17.8)	25.69±3.01 (22.7-34.1)
21-30 n = 1213	1.90±0.20 (1.6-2.8)	55.25±3.66 (46.2-64.7)	55.57±24.99 (24-120)	2.30±0.39 (1.6-4.2)	64.27±5.73 (50.0-78.5)	15.95±5.37 (10.3-27.6)	26.29±2.13 (21.9-33.0)
31-40 n = 1419	1.91±0.19 (1.5-2.8)	55.03±3.94 (42.3-68.8)	51.41±16.48 (19.2-110)	2.29±0.34 (1.6-3.9)	64.10±4.91 (50.8-77.6)	13.36±3.68 (5.6-21.8)	25.98±2.41 (21.7-34.9)
41-50 n = 1103	1.95±0.17 (1.6-2.6)	53.76±3.8 (42.0-63.8)	46.89±15.9 (20.2-96)	2.36±0.34 (1.6-3.6)	63.04±5.59 (46.7-78.7)	13.9±5.59 (7.2-31.8)	27.65±2.82 (23.3-35.9)
51-60 n = 766	1.98±0.2 (1.6-2.7)	52.93±3.95 (40.7-62.5)	46.76±16.3 (22.4-83)	2.42±0.34 (1.7-3.7)	61.69±5.35 (50.0-75.6)	13.18±4.57 (6.7-19.6)	27.78±2.73 (23.6-36.7)
61-70 n = 399	2.06±0.2 (1.8-2.7)	50.39±3.44 (44.4-57.8)	34.79±18.12 (8.8-72)	2.56±0.49 (1.8-4.2)	60.48±6.2 (46.8-72.5)	9.65±5.41 (1.9-15.5)	28.79±2.65 (25.7-35.5)
71-80 n = 287	2.26±0.28 (2.0-2.8)	50.7±3.02 (47.5-57.1)	32.17±14.7 (18.6-65.3)	3.0±0.5 (2.3-3.6)	55.74±3.61 (51.6-62.2)	8.65±4.47 (5.94-18.1)	31.88±3.11 (28.8-36.9)
>80 n = 189	3.1±0.28 (2.9-3.3)	49.55±1.63 (48.4-50.7)	27.9±10.4 (11.3-54.1)	3.4±0.71 (2.9-3.9)	53.25±6.15 (48.9-57.6)	7.49±4.85 (3.98-13.6)	33.0±1.75 (30.7-34.7)

The values are presented as mean±SD, n = number, SL = sensory latency; SNCV = sensory nerve conduction velocity; SNAPA = sensory nerve action potential amplitude, DML = distal motor latency measured from the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak. The values between brackets represent the range.

Table 4: Radial Nerve Parameters in Different Age Groups

Age Group (years)	SL (msec)	SNCV (m/sec)	SNAPA (μV)	DML (msec)	MNCV (m/sec)	CMAPA (mV)	F-wave (msec)
< 1 n = 219	1.25±0.07 (1.2-1.3)	49.6±5.94 (45.4-53.8)	36.5±8.43 (18.33-52.3)	1.85±0.07 (1.8-1.9)	51.15±1.63 (50.0-52.3)	8.21±4.32 (5.34-15.6)	19.0±2.12 (17.5-20.5)
1-10 n = 476	1.72±0.26 (1.2-2)	53.41±3.07 (45.4-56.7)	47.22±13.54 (32.4-69.9)	2.2±0.23 (1.8-2.5)	56.62±3.32 (50-60.1)	13.99±10.2 (6.98-20.5)	21.53±1.99 (17.5-24.1)
11-20 n = 559	1.8±0.17 (1.5-2.2)	54.68±4.95 (50.0-68.7)	54.76±11.39 (39.8-74.8)	2.94±0.48 (2.0-4.0)	58.82±4.53 (50.0-69.0)	12.87±7.65 (5.91-19.3)	27.4±2.67 (21.2-30.1)
21-30 n = 984	1.91±0.3 (1.5-2.5)	52.41±4.94 (43.3-62.5)	55.45±17.9 (34.1-95.2)	3.12±0.89 (1.7-5.3)	60.68±7.25 (50.8-77.2)	14.39±9.73 (8.3-21.3)	26.24±3.13 (20.6-31.1)
31-40 n = 1123	1.73±0.24 (1.4-2.3)	54.9±4.41 (47.5-66.6)	50.21±12.1 (24.2-87.9)	2.71±0.66 (1.5-3.4)	61.17±7.36 (53.0-70.0)	13.98±6.77 (8.6-24.8)	28.66±2.9 (23.7-32.2)

41-50 n = 895	1.78±0.31 (1.4-2.4)	53.71±4.4 (45.6-60.7)	45.7±10.3 (28.2-78.9)	3.34±1.01 (1.8-5.0)	54.36±6.79 (47.5-65.9)	13.0±5.11 (6.6-23.8)	29.33±1.9 (25.8-31.3)
51-60 n = 766	2.05±0.5 (1.8-2.8)	53.9±5.59 (49.0-61.1)	44.24±12.83 (18.7-69.9)	3.58±0.56 (2.9-4.4)	58.9±7.92 (52.2-68.5)	13.76±7.57 (5.57-15.6)	28.58±1.04 (27.6-29.9)
61-70 n = 402	2.57±0.45 (2.1-3.0)	50.35±3.14 (47.6-54.8)	37.79±18.2 (18.8-76.3)	3.7±0.47 (3.1-4.2)	54.38±3.7 (50.1-59.1)	10.77±5.29 (2.6-17.3)	29.08±3.02 (25.8-33.1)
71-80 n = 195	2.21±0.31 (2.1-2.9)	48.7±4.52 (44.4-55.4)	27.2±10.96 (17.3-49.73)	3.3±0.54 (2.8-4.2)	50.24±4.16 (46.9-58.4)	9.29±4.88 (3.8-14.4)	33.6±3.12 (29.1-34.9)

The values are presented as mean±SD, n = number, SL = sensory latency; SNCV = sensory nerve conduction velocity; SNAPA = sensory nerve action potential amplitude, DML = distal motor latency measured from the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak. The values between brackets represent the range.

Table 5: Musculocutaneous Nerve Parameters in Different Age Groups

Age Group (years)	SL (msec)	SNCV (m/sec)	SNAPA (μV)	DML (msec)	MNCV (m/sec)	CMAPA (mV)
1-10 n = 211	2.0±0.1 (1.4-2.5)	51.2±2.4 49.2-55.2)	10.1±3.2 (7.9-14.2)	3.98±0.3 (3.6-4.4)	50.4±4.26 (44.7-56.3)	10.9±4.13 (7.3-15.4)
11-20 n = 327	2.3±0.1 (1.8-2.7)	56.3±3.2 50.1-58.2)	12.1±3.2 (8.2-14.2)	4.25±0.64 (3.4-4.9)	59.8±6.33 (52.1-67.6)	13.1±8.64 (7.3-27.4)
21-30 n = 300	2.8±0.3 (2.1-0.5)	65.1±4.5 59.8-69.33)	14.2±5.4 (9.3-16.4)	4.44±0.42 (3.8-5.2)	64.84±6.04 (53.9-71.4)	15.9±7.94 (6.85-26.1)
31-40 n = 380	2.9±0.5 (2.1-0.61)	62.3±4.7 (59.4-69.2)	13.6±4.8 (9.2-17.7)	4.57±0.53 (3.9-5.6)	65.18±6.91 (51.7-76.2)	14.2±6.43 (6.25-24.7)
41-50 n = 433	3.1±0.51 (2.4-0.52)	64.3±5.1 (58.7-68.4)	13.4±5.21 (8.6-16.9)	4.98±0.79 (3.9-6.5)	63.21±6.72 (50.5-73.0)	13.8±5.43 (6.2-22.3)
51-60 n = 265	3.2±0.53 2.6-0.55)	60.3±5.22 (56.9-66.1)	11.4±4.7 (7.3-15.6)	4.71±0.36 (4.0-5.1)	64.69±6.75 (52.1-74.4)	10.6±6.7 (5.7-21.4)
61-70 n = 189	3.3±0.57 (2.7-0.81)	58.3±5.3 (52.8-63.1)	10.3±4.6 (6.2-13.3)	5.33±0.61 (4.8-6.0)	50.33±7.09 (42.7-56.7)	8.65±7.33 (5.7-19.2)

The values are presented as mean±SD, n = number, SL = sensory latency; SNCV = sensory nerve conduction velocity; SNAPA = sensory nerve action potential amplitude, DML = distal motor latency measured from the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak. The values between brackets represent the range.

Table 6: Axillary Nerve Parameters in Different Age Groups

Age Group (years)	DML (msec)	MNCV (m/sec)	CMAPA (mV)
1-10 n = 209	4.56±0.67	46.24±5.24	10.43±4.83
11-20 n = 327	3.58±0.49	54.37±2.41	13.7±5.2
21-30	3.9±0.59	54.91±6.61	17.4±6.87

n = 300			
31-40 n = 376	4.3±0.24	52.87±3.6	11.6±5.1
41-50 n = 420	4.23±0.54	52.3±5.66	12.5±4.8
51-60 n = 265	4.82±0.39	52.18±3.01	9.98±5.73
61-70 n = 180	5.3±0.76	49.88±1.65	8.7±3.7

The values are presented as mean±SD, n = number, DML = distal motor latency measured fro the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak.

Table 7: Tibial Nerve Parameters in Different Age Groups

Age Group (years)	SL (msec)	SNCV (m/sec)	SNAPA (μV)	DML (msec)	MNCV (m/sec)	CMAPA (mV)	F-wave (msec)
< 1 n = 213	2.1±0.29 (1.8-2.5)	35.35±8.52 (24.0-44.7)	12.4±8.23 (7.3-28.9)	2.93±0.94 (2.0-4.2)	45.28±11.3 (35.0-57.5)	7.5±4.6 (4.1-15.4)	24.76±2.61 (21.0-28.2)
1-10 n = 422	2.56±0.56 (1.5-4.2)	46.48±5.48 (30.7-57.1)	15.2±10.5 (8-32.3)	3.02±0.73 (1.8-4.7)	50.46±5.45 (40.7-64.0)	10±6.65 (5.1-18.2)	30.15±5.84 (21.7-45.2)
11-20 n = 513	4.0±0.55 (2.4-4.7)	46.18±4.22 (40.0-58.7)	15.6±6.57 (5.2-21.9)	3.82±0.5 (2.4-4.7)	51.49±4.73 (42.3-65.5)	9.8±4.78 (4.2-19.6)	46.9±5.06 (38.3-56.8)
21-30 n = 822	4.23±0.52 (3.0-5.7)	44.19±3.89 (36.0-57.8)	13.26±5.28 (9.2-28)	4.08±0.65 (2.9-6.3)	50.29±5.67 (41.7-66.9)	8.7±4.53 (3.2-16.4)	48.74±4.45 (40.4-57.5)
31-40 n = 1213	4.17±0.53 (3.0-5.5)	43.93±4.28 (33.0-55.0)	10.97±3.9 (4.8-16.2)	4.08±0.61 (3.0-5.5)	50.6±5.3 (40.2-65.9)	9.95±3.5 (5.1-15.7)	49.02±4.34 (40.0-61.0)
41-50 n = 1544	4.34±0.51 (3.2-5.9)	42.68±3.68 (33.0-54.4)	9.95±3.39 (7.7-20.8)	4.25±0.62 (3.0-5.9)	48.92±5.05 (40.0-61.8)	8.5±4.93 (4.2-18.5)	51.45±4.39 (41.5-61.8)
51-60 n = 877	4.27±0.42 (3.3-5.0)	41.39±4.71 (24.1-50.0)	9.98±4.6 (6.8-18.6)	4.01±0.61 (3.0-5.5)	47.24±4.0 (41.8-57.1)	9.54±5.34 (4.3-16.9)	51.55±5.12 (44.6-64.1)
61-70 n = 419	4.37±0.57 (3.5-5.5)	40.64±4.08 (32.6-47.3)	8.95±7.1 (6-15.9)	4.35±0.72 (3.3-6.9)	46.65±4.41 (38.3-57.0)	6.2±3.28 (3.8-10.4)	52.36±5.53 (42.5-61.9)
71-85 n = 185	4.89±0.74 (4.0-6.2)	37.54±3.63 (32.2-41.8)	5.67±8.4 (3.5-16.7)	4.64±1.3 (2.5-8.4)	46.71±3.59 (38.5-51.6)	5.9±4.1 (4.1-11.5)	53.48±4.74 (49.3-63.2)

The values are presented as mean±SD, n = number, SL = sensory latency; SNCV = sensory nerve conduction velocity; SNAPA = sensory nerve action potential amplitude, DML = distal motor latency measured from the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak. The values between brackets represent the range.

Table 8: Common peroneal Nerve Parameters in Different Age Groups

Age Group (years)	SL (msec)	SNCV (m/sec)	SNAPA (μV)	DML (msec)	MNCV (m/sec)	CMAPA (mV)	F-wave (msec)
< 1 n = 209	2.07±0.28 (1.8-2.6)	33.93±5.87 (25.8-42.1)	8.99±7.61 (4.1-15.7)	2.63±0.67 (1.8-3.9)	47.88±5.46 (40.0-54.0)	4.3±3.11 (2.6-7.91)	26.13±2.92 (24.4-29.5)
1-10 n = 420	2.48±0.43 (1.9-3.5)	41.92±4.25 (31.0-50.0)	14.47±8.11 (9.8-24.6)	2.77±0.61 (1.9-4.3)	48.27±3.6 (43.0-55.0)	9.11±4.1 (4.5-12.4)	31.46±7.08 (24.2-45.3)
11-20 n = 513	3.31±0.44 (2.0-4.0)	43.42±3.25 (38.2-52.5)	15.6±6.57 (7.85-26.4)	3.77±0.51 (2.5-4.7)	50.48±4.1 (43.8-60.6)	9.2±5.12 (5.7-14.8)	47.65±3.21 (41.6-51.2)
21-30 n = 822	3.51±0.39 (2.6-4.3)	43.39±3.33 (37.8-55.1)	11.67±5.4 (5.8-21.2)	3.64±0.62 (2.4-5.5)	50.6±5.07 (40.0-68.0)	8.9±2.31 (5.6-10.9)	47.68±3.86 (40.5-58.4)
31-40 n = 1213	3.42±0.45 (2.2-4.5)	43.5±3.88 (33.3-63.6)	13.2±7.52 (4.8-23.7)	3.75±0.62 (2.2-5.4)	51.11±4.34 (42.7-60.0)	8.13±4.29 (4.8-13.3)	48.71±4.23 (40.4-59.5)
41-50 n = 1534	3.62±0.36 (3.2-4.6)	40.87±3.16 (31.5-45.7)	14.8±10.58 (7.6-28.2)	3.82±0.73 (2.7-5.7)	49.2±4.19 (40.1-58.0)	9.72±4.02 (4.1-13.8)	48.91±5.09 (41.1-59.9)
51-60 n = 860	3.56±0.42 (3.0-4.8)	40.22±3.91 (32.0-48.4)	10.15±5.35 (4.9-17.4)	3.8±0.71 (2.7-5.2)	47.32±4.51 (39.5-55.2)	8.43±5.1 (3.8-14.7)	50.24±4.26 (42.9-57.7)
61-70 n = 400	3.5±0.29 (3.1-4.1)	40.59±2.36 (36.7-45.1)	9.9±6.8 (3.9-16.8)	3.59±0.42 (2.9-4.2)	48.19±4.53 (41.1-60.0)	5.58±3.31 (2.7-11.8)	49.92±4.53 (40.8-56.1)
71-85 n = 180	3.83±0.63 (2.7-4.7)	38.81±3.68 (32.6-44.4)	6.41± 3.5 (3.1-10.9)	3.51±0.46 (3.0-4.5)	48.53±3.66 (44.1-55.7)	5.86±2.76 (3.2-10.8)	50.49±2.66 (47.0-54.0)

The values are presented as mean±SD, n = number, SL = sensory latency; SNCV = sensory nerve conduction velocity; SNAPA = sensory nerve action potential amplitude, DML = distal motor latency measured from the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak. The values between brackets represent the range.

Table 9: Femoral Nerve Parameters in Different Age Groups

Age Group (years)	DML (msec)	MNCV (m/sec)	CMAPA (mV)
1-10 (n = 155)	3.1±0.12	50.1±4.7	9.11±4.1
11-20 (n = 344)	3.68±0.18	55.42±5.3	9.2±5.12
21-30 (n = 426)	4.38±0.6	53.5±5.03	8.9±2.31
31-40 (n = 587)	4.53±0.4	50.03±8.11	8.13±4.29
41-50 (n = 630)	5.07±0.23	52.7±4.37	9.72±4.02
51-60 (n = 288)	5.33±0.46	46.8±3.31	8.43±5.1
61-70 (n = 276)	6.0±0.96	41.43±4.2	5.58±3.31

The values are presented as mean±SD, n = number, DML = distal motor latency measured from the onset of action potential, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude measured from peak to peak.

Table 10: Comparison of nerve conduction parameters of facial, musculocutaneous, axillary, and femoral nerves between the present study and those reported by others.

Facial Nerve	Present study (n = 1793)	Kimura[19]	Waylonis & Johnson[20] (n = 78)	Taylor et al[21]	
DML	3.14±0.37	2.9±0.4	3.4±0.8	4.0±0.5	
MCV	31.07±2.74	----	----	----	
CMAPA	8.75±3.61	----	----	----	
Axillary Nerve	Present study (n = 1868)	Kraft[22] (n = 62)			
DML	4.31±0.73	3.9±0.5			
MCV	52.98±4.34	----			
CMAPA	10.9±3.62	----			
Musculocutaneous Nerve	Present study (n = 1894)	Kraft[22] (n = 62)	Izzo et al[23] (n = 155)	Reddy et al[24] (n = 30)	Spindler & Felsenthal[25] (n = 30)
SL	2.8±0.3	4.5±0.6	2.7±0.2	2.7±0.2	1.8±0.1
SNCV	65.1±4.5	----	63.0±5.0	66.0±4.0	65.0±3.6
SNAPA	14.2±5.4	----	11.4±5.2	15.4±4.1	24.0±7..2
DML	4.68±0.62	----	----	----	----
MCV	62.25±7.92	----	----	----	----
CMAPA	15.05±4.2	----	----	----	----
Femoral Nerve	Present study (n = 2551)	Uludag et al[15] (n = 16)	Gassel [26] (n = 42)	Johnson et al[27]	
DML	4.51±0.71	4.6±0.5	3.7±0.45	6.0±0.7	
MCV	52.07±5.56	----	70.0±5.5	69.4±9.2	
CMAPA	8.44±3.16	----	----		

The values are presented as mean±SD, n = number, SL = sensory latency, SNCV = sensory nerve conduction velocity, SNAPA = sensory nerve action potential amplitude, DML = distal motor latency, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude

Table 11: Comparison of nerve conduction parameters of median, ulnar, and radial nerves between the present study and those reported by others.

Median Nerve	Present study (n = 5766)	Hennessey et al[8] (n = 44)	Shehab[14] (n = 50)	Awang et al[16] (n = 250)	Kimura[18] (n = 65)	Karagoz et al[28] (n = 17)
SL	1.93±0.22	2.5±0.2	2.3±0.3	----	2.84±0.34	----
SNCV	51.9±4.04	61.2±4.3	56.6±7.6	54.04±7.02	56.2±5.8	61.4±3.0
SNAPA	49.5±23.1	31.4±8.2	71.3±23.9	----	38.5±15.6	36.6±6.6
DML	3.39±0.47	3.2±0.4	3.1±0.3	----	3.49±0.34	----
MNCV	58.97±4.8	59.5±4.4	56.5±3.5	54.71±5.69	57.7±4.9	59.3±3.2
CMAPA	14.8±4.92	12.1±3.8	11.1±2.8	----	7.0±3.0	8.3±1.4
Ulnar Nerve	Present study (n = 5519)	Shehab[14] (n = 50)	Awang et al[16] (n = 250)	Kimura[18] (n = 65)	Karagoz et al[28] (n = 17)	Buschbacher[29] (n = 248)
SL	1.94±0.19	2.0±0.2	2.0±0.2	2.54±0.29	----	----
SNCV	54.2±3.97	52.1±7.5	52.1±7.5	54.8±5.3	58.5±3.7	----
SNAPA	50.1±19.8	59.2±17.6	59.2±17.6	35.0±13.4	29.7±4.0	----
DML	2.35±0.39	2.4±0.3	2.4±0.3	2.59±0.39	----	3.0±0.3
MNCV	63.2±5.61	60.4±5.2	60.4±5.2	58.7±5.1	59.7±3.7	61.0
CMAPA	13.8±4.86	9.2±2.2	9.2±2.2	5.7±2.0	12.3±2.0	11.6±2.1
Radial Nerve	Present study (n = 4729)	Falco et al[9] (n = 51)	Johnson et al[13] (n = 78)	Shehab[14] (n = 50)	Jebsen[30] (n = 49)	Trojaborg & Sinrup[31]
SL	1.94±0.33	2.0±0.2	2.4±0.2	1.95±0.3	----	----
SNCV	53.44±4.42	----	----	53.1±8.7	----	58.0±6.0
SNAPA	26.9±13.98	16.5±13.8	12.0±1.0	18.6±5.5	----	13.0±7.5
DML	3.27±0.72	----	----	----	----	----
MNCV	58.84±6.32	----	----	----	61.1±5.9	62.0±5.1
CMAPA	16.1±5.23	----	----	----	----	14.0±8.8

The values are presented as mean±SD, n = number, SL = sensory latency, SNCV = sensory nerve conduction velocity, SNAPA = sensory nerve action potential amplitude, DML = distal motor latency, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude

Table 12: Comparison of nerve conduction parameters of tibial and common peroneal nerves between the present study and those reported by others.

Tibial Nerve	Present study (n = 5388)	Kimura[18] (n = 59)	Buschbacher[32] (n = 250)	Budak[33] (n = 30)	Antunes et al[34] (n = 51)
SL	4.22±0.52	----	----	----	4.84±0.71
SNCV	43.45±4.35	----	----	----	46.1±5.68
SNAPA	12.73±5.2	----	----	----	2.13±1.78
DML	4.09±0.63	3.96±1,0	4.5±0.8	----	4.36±0.67
MNCV	49.59±5.26	48.5±3.6	44-51	47.1±3.0	----
CMAPA	8.97±4.45	5.8±1.9	12.7±4.4	----	20.25±7.57
Common Peroneal Nerve	**Present study (n = 5342)**	**Kimura[18] (n = 60)**	**Karagoz et al[28] (n = 17)**	**DiBenedetto[35] (n = 50)**	**Buschbacher[36] (n =242)**
SL	3.49±0.41	----	----	2.24±0.49	----
SNCV	42.5±3.71	----	----	47.3±3.4	----
SNAPA	14.26±7.86	----	----	13.9±4.0	----
DML	3.73±0.63	3.77±0.86	----	----	4.8±0.8
MNCV	49.96±4.76	48.3±3.9	57.4±3.6	----	46.5±4.5
CMAPA	8.22±3.61	5.1±2.3	7.6±1.6	----	6.8±2.5 (young) 5.1±2.5 (old)

The values are presented as mean±SD, n = number, SL = sensory latency, SNCV = sensory nerve conduction velocity, SNAPA = sensory nerve action potential amplitude, DML = distal motor latency, MNCV = motor nerve conduction velocity, CMAPA = compound muscle action potential amplitude

Table 13: Comparison of F-wave latency of median, ulnar, radial, tibial, and common peroneal nerves between the present study and those reported by others.

Nerve	Present study	Alavian-Ghavanini & Haghpanah[17] (n = 73)	Kimura[18] (n = 61)	Budak[33] (n = 30)	Buschbacher[37-39]
Median (n = 3244)	27.23±2.46	-----	26.6±2.2	-----	26.8±2.4 (n = 195)
Ulnar (n = 4681)	26.86±2.41	-----	27.6±2.2	25.7±2.6	-----
Radial (n = 2199)	27.74±2.78	-----	-----	-----	-----
Tibial (n = 2877)	49.74±4.87	46.54±3.94	47.7±5.0	48.0±3.9	50.8±5.3 (n = 159)
Common peroneal (n = 2084)	48.59±4.26	46.06±3.85	48.4±4.0	-----	50.2±5.5 (n = 180)

The values are presented as mean±SD, n= number

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