Research Article

Standard norms of nerve conduction studies in a sample of healthy individuals in Minia Governorate

Amal T. Khafagi, Nermin A. Hamdy, Enas M. Hasan, Muhammad M. Ismail, Mohamed M. Abdelkader, Rasha N. Saleh and Reham B. Mohamed
Department of Neurology, Minia University, Egypt.

Abstract
Background: All electromyography (EMG) laboratories should depend on certain norms for nerve conduction studies (NCSs), whether these norms developed internally or following another laboratory. **Objective:** The majority of research studying standard norms of NCSs were based on non-Egyptian subjects. Therefore, we planned to study standard norms and the effect of certain factors (e.g. age, height and body mass index) on routine nerve conduction studies among healthy individuals in Minia governorate. **Patients and Methods:** Ninety healthy subjects living in Minia governorate, (41males and 49 females) ranging in age - at time of examination - from 5 to 67 years were included in this study. Tests performed were motor and sensory nerve conduction studies and F waves for right median and ulnar nerves; in addition to motor nerve conduction study for right posterior tibial and common peroneal nerves, F wave study for right posterior tibial nerve and sensory nerve conduction study of right sural nerve. **Results:** Collectively normal values obtained in our study agree to a great extent with values given by previous researchers and published in literature. Age, height and limb length showed significant influence on these norms, and to a lesser extent the body mass index. But sex did not show significant influence. **Conclusion:** Studying the standard norms of routine nerve conduction studies is mandatory before examining patients with different types of neuropathies. The examiner must be aware by the effect of different factors especially age, height, limb length and body mass index on these variables.
Keywords: Standard Norms, Nerve Conduction Studies, Minia Governorate.

Introduction
Routine nerve conduction studies (NCSs) usually include motor and sensory nerve conduction studies and F-waves. These studies involve analysis of specific parameters, including latency, amplitude, and conduction velocity. [1] All electromyography (EMG) laboratories should depend on certain norms for nerve conduction studies, whether these norms developed internally or following another laboratory.[2]

Aim
To study the standard norms in routine nerve conduction studies among healthy individuals in Minia governorate, and to study the effect of age, sex, height, limb length and body mass index on these parameters.

Patients and Methods
Ninety healthy subjects living in Minia governorate, (41males and 49 females) ranging in age - at time of examination - from 5 to 67 years were included in this study. They have been examined in the neurophysiology unit of neurology department in Minia University Hospital, after submitting a verbal consent to be included in this study, in the period between December 2013 to June 2014. All were subjected to detailed history taking and meticulous general and neurological examination. Children under the age of 5 years, evidence of any neurological or general medical disorder, history of chronic drug intake and history of limb trauma or surgery were all exclusion criteria. We used Neuropack MEB-2300 6 channel EMG/EP measuring system; Nihon Kohden Corporation, Tokyo, Japan. Tests performed were motor and sensory nerve conduction studies and F waves for right median and ulnar nerves; in addition to motor nerve conduction study for right posterior tibial and common peroneal nerves, F wave study for right posterior tibial nerve and sensory nerve conduction study of right sural nerve. Temperature was kept above 29° C.

Regarding the **median nerve** motor conduction study, recording was done from Abductor Pollicis Brevis muscle and stimulation was at wrist and elbow (In individuals older than 12 years, stimulation was done 8 cm proximal to the active electrode and at elbow respectively). Cathode of the stimulator will be proximal to the anode while performing F wave studies. Regarding the median nerve sensory conduction study, that was done using orthodromic technique with stimulation at the middle finger (Cathode over the metacarpo-phalangeal joint and anode 3cm distal to it) and recording at wrist.

Regarding the **ulnar nerve** motor conduction study, recording was done from Abductor Digiti Minimi muscle and stimulation was at wrist, below elbow and above elbow (In individuals older than 12 years, stimulation was done 8 cm proximal to the active electrode, 4 cm distal to medial epicondyle and 10 cm proximal to stimulation point 2 respectively). Cathode of the stimulator will be proximal to the anode while performing F wave studies. Regarding the ulnar nerve sensory conduction study, that was done using orthodromic technique with stimulation at the little finger (Cathode over the metacarpo-phalangeal joint and anode 3cm distal to it) and recording at wrist.

Regarding the **posterior tibial nerve** motor conduction study, recording was done from Abductor Hallucis Brevis muscle and stimulation was at ankle and popliteal fossa (In individuals older than 12 years, stimulation was done 8 cm proximal to the active electrode and at mid-popliteal fossa respectively). Cathode of the stimulator will be proximal to the anode while performing F wave studies.

Regarding the **common peroneal nerve** motor conduction study, recording was done from Extensor Digitorum Brevis muscle and stimulation was at ankle and fibula head (In individuals older than 12 years, stimulation was done 8 cm proximal to the active electrode and posterior and inferior to fibula head respectively).

Regarding the **sural nerve** sensory conduction study, that was done using antidromic technique with recording from behind the medial malleolus and stimulation 14 cm proximal to the active electrode slightly lateral to the midline of the posterior lower aspect of the leg.

Statistical Analysis

Statistical analyses were performed using the SPSS statistics version 16. Differences in the mean of continuous variables were analyzed using parametric test (Independent sample T test, One way ANOVA test). And differences between categorical variables were analyzed using Chi Square test. The associations between continuous variables were determined using Pearson Product-Moment Correlation. For all tests, the values $P<0.05$ were regarded statistically significant.

Results

Ninety healthy subjects living in Minia governorate, (41males and 49 females) ranging in age - at time of examination - from 5 to 67 years (26.2 ± 18.6) were included in this study.

Regarding **age**, distal motor latency (DML) has been shown to be significantly delayed with age in median, posterior tibial and common peroneal motor nerve conduction studies. Motor conduction velocity (MCV) was also significantly slower with age in posterior tibial motor nerve conduction study (Table 1). F-M latency was significantly prolonged with age in median, ulnar and posterior tibial nerves (Table 2). However, in sensory nerve conduction studies, sensory nerve action potential (SNAP) amplitudes were significantly smaller in elderly during median and sural sensory nerve conduction studies. Moreover, sensory conduction velocity was significantly reduced in elderly in median sensory nerve conduction study (Table 3).

Regarding **sex**, the studied parameters did not show significant differences in between males and females.

Regarding the correlation between **height** and motor nerve conduction study parameters, the DML of median, posterior tibial and common peroneal nerves showed positive statistically significant correlation with height. Moreover, cMAP amplitude showed positive statistically significant correlation with height in ulnar nerve above elbow amplitude, common peroneal nerve distal and proximal amplitudes and posterior tibial proximal amplitude. In the other hand, MCV of the posterior tibial nerve showed negative statistically significant correlation with height (Table 4). F-M latencies of median, ulnar and posterior tibial nerves showed highly significant positive correlation with height (Table 5). Regarding the correlation between height and sensory nerve conduction study parameters, the SNAP amplitude of the sural nerve showed positive statistically significant correlation with height (Table 6).

Regarding the correlation between **limb length** and motor nerve conduction study parameters, the DML of median and common peroneal nerves showed positive statistically significant correlation with limb length. Moreover, cMAP amplitude showed positive statistically significant correlation with limb length in median nerve proximal amplitude and common peroneal nerve distal amplitude (Table 7). Regarding the correlation between **body mass index** and motor nerve conduction study parameters, the DML of median and posterior tibial nerves showed positive statistically significant correlation with body mass index (Table 10). F-M latencies of median, ulnar and posterior tibial nerves showed highly significant positive correlation with both limb length and body mass index (Table 8 and 11). Regarding the correlation between both limb length and body mass index and sensory nerve conduction study parameters, results were no statistically significant (Table 9 and 12).

Table (1): Comparison of Median, Ulnar, Posterior Tibial and Common Peroneal motor nerve conduction study parameters between the three age groups:

Studied Parameter	Children (5-12y) n=23	Adults (13-40y) n=47	Elderly(>40y) n=18	P. value
Median Nerve				
DML (msec)	2.6±0.4	3.1±0.5	3.3±0.5	**<0.001****
D amp (mV)	8.8±2.4	9.1±2.7	7.7±2.7	**0.1**
P amp (mV)	7.9±2.2	8.6±2.7	7.1±2.3	**0.09**
MCV (m/sec)	56.2±3.9	55.9±4.2	55.8±4.7	**0.9**
Ulnar Nerve				
DML (msec)	1.9±0.6	2.1±0.5	2.3±0.7	**0.07**
Amp 1 (mV)	8.1±2.7	8.5±2.5	7.9±1.9	**0.6**
Amp 2 (mV)	7.3±2.6	7.8±2.4	6.8±1.5	**0.2**
Amp 3 (mV)	-	6.8±1.5	6.7±1.5	**0.2**
MCV1 (m/sec)	60.3±5.1	59.7±4.9	60.3±4.7	**0.8**
MCV 2 (m/sec)	-	57.1±5.5	58.7±5.6	**0.3**
Posterior Tibial nerve				
DML (msec)	2.9±0.8	3.4±0.6	3.5±0.5	**<0.002****
D amp (mV)	11.8±3.3	10.4±3.3	10.4±3.3	**0.2**
P amp (mV)	10.3±2.8	8.6±2.9	8.4±3.0	**0.06**
MCV (m/sec)	51.3±3.7	49.4±3.3	48.6±3.1	**0.01***
Common Peroneal Nerve				
DML (msec)	2.7±0.5	3.4±0.5	3.5±0.5	**<0.001****
D amp (mV)	4.8±1.5	5.7±2.1	5.1±2.8	**0.2**
P amp (mV)	4.4±1.6	5.0±2.0	4.0±1.2	**0.1**
MCV (m/sec)	51.8±3.6	50.6±4.1	50.0±2.8	**0.3**

DML: distal motor latency, **msec:** millisecond, **D amp:** distal compound motor action potential (cMAP) amplitude, **mv:** millivolt, **P amp**: proximal cMAP amplitude, **MCV:** motor conduction velocity **m/sec:** meter per second. **Amp1:** distal cMAP amplitude at wrist stimulation, **Amp2:** cMAP amplitude at below elbow stimulation, **Amp3:** cMAP amplitude at above elbow stimulation.

Table (2): Comparison of Median, Ulnar, Posterior Tibial and Common Peroneal nerves F-M latency between the three age groups:

Nerve	Children (5-12y) n=23	Adults (13-40y) n=48	Elderly (>40y) n=19	P. value
Median	20.7±1.6	25±2.2	26.7±2.4	**<0.001****
Ulnar	20.5±1.6	25.5±2.4	26.4±2.2	**<0.001****
Posterior Tibial	35.4±3.9	44.9±3.8	46.6±4.3	**<0.001****

Table (3): Comparison of Median, Ulnar and Sural sensory nerve conduction study parameters between the three age groups:

Studied Parameter	Children (5-12y) n=23	Adults (13-40y) n=48	Elderly (>40y) n=19	P. value
Median Nerve:				
-SNAP amp (µv)	17.2±4.7	19.1±5.0	14.9±5.2	**0.01***
-SCV (m/sec)	51.2±4.1	50.5±4.1	46.4±10.6	**0.01***
Ulnar Nerve:				
-SNAP amp (µv)	12.1±5.9	12.1±3.7	9.7±3.5	**0.2**
-SCV (m/sec)	49.9±3.3	50.0±5.3	49.8±3.2	**0.5**
Sural Nerve:				
-SNAP amp (µv)	12.8±4.0	16.2±6.6	13.0±3.3	**0.01***
-SCV (m/sec)	48.7±3.2	48.6±3.2	47.0±8.5	**0.1**

SNAP amp: sensory nerve action potential amplitude, **µv:** microvolt, **SCV:** sensory conduction velocity, **m/sec:** meter per second.

Table (4): Correlation of height with motor nerve conduction study parameters

Studied Parameter	r	P
Median Nerve		
DML (msec)	**0.47****	**<0.001****
D amp (mV)	0.08	0.4
P amp (mV)	0.14	0.1
MCV (m/sec)	0.05	0.6
Ulnar Nerve		
DML (msec)	0.21	0.05
Amp 1 (mV)	0.03	0.6
Amp 2 (mV)	0.06	0.7
Amp 3 (mV)	**0.36****	**0.003****
MCV1 (m/sec)	0.1	0.3
MCV 2 (m/sec	0.07	0.5
Posterior Tibial Nerve		
DML (msec)	**0.31****	**0.003****
D amp (mV)	0.14	0.1
P amp (mV)	**0.21***	**0.04***
MCV (m/sec)	**-0.21***	**0.04***
Common Peroneal Nerve		
DML (msec)	**0.46****	**<0.001****
D amp (mV)	**0.26***	**0.01***
P amp (mV)	**0.21***	**0.04***
MCV (m/sec)	-0.09	0.3

DML: distal motor latency, **msec:** millisecond, **D amp:** distal compound motor action potential (cMAP) amplitude, **mv:** millivolt, **P amp**: proximal cMAP amplitude, **MCV:** motor conduction velocity **m/sec:** meter per second. **Amp1:** distal cMAP amplitude at wrist stimulation, **Amp2:** cMAP amplitude at below elbow stimulation, **Amp3:** cMAP amplitude at above elbow stimulation.

Table (5): Correlation of height with F-M latencies

Studied Nerve	r	P
Median	**0.70****	**<0.001****
Ulnar	**0.78****	**<0.001****
Posterior Tibial	**0.81****	**0.001****

Table (6): Correlation of height with sensory nerve conduction study parameters

Studied Parameter	r	P
Median Nerve:		
-SNAP amp (µv)	0.079	0.4
-SCV (m/sec)	-0.04	0.6
Ulnar Nerve:		
-SNAP amp (µv)	-0.054	0.6
-SCV (m/sec)	0.09	0.3
Sural Nerve:		
-SNAP amp (µv)	**0.22***	**0.04***
-SCV (m/sec)	-0.09	0.3

SNAP amp: sensory nerve action potential amplitude, **µv:** microvolt, **SCV:** sensory conduction velocity, **m/sec:** meter per second.

Table (7): Correlation of limb length with motor nerve conduction study parameters

Studied Parameter	r	P
Median Nerve		
DML (msec)	**0.37****	**0.001****
D amp (mV)	0.15	0.1
P amp (mV)	**0.21***	**0.04***
MCV (m/sec)	0.02	0.8
Ulnar Nerve		
DML (msec)	0.15	0.1
Amp 1 (mV)	0.03	0.7
Amp 2 (mV)	-0.02	0.8
Amp 3 (mV)	-0.21	0.09
MCV1 (m/sec)	0.07	0.5
MCV 2 (m/sec	-0.05	0.7
Posterior Tibial Nerve		
DML (msec)	0.19	0.06
D amp (mV)	-0.01	0.9
P amp (mV)	-0.07	0.4
MCV (m/sec)	-0.10	0.3
Common Peroneal Nerve		
DML (msec)	**0.35****	**0.001****
D amp (mV)	**0.28****	**0.007****
P amp (mV)	0.26	0.1
MCV (m/sec)	-0.01	0.9

DML: distal motor latency, **msec:** millisecond, **D amp:** distal compound motor action potential (cMAP) amplitude, **mv:** millivolt, **P amp**: proximal cMAP amplitude, **MCV:** motor conduction velocity **m/sec:** meter per second. **Amp1:** distal cMAP amplitude at wrist stimulation, **Amp2:** cMAP amplitude at below elbow stimulation, **Amp3:** cMAP amplitude at above elbow stimulation.

Table (8): Correlation of limb length with F-M latencies

Studied Nerve	r	P
Median	**0.58****	**<0.001****
Ulnar	**0.6****	**<0.001****
Posterior Tibial	**0.77****	**0.001****

Table (9): Correlation of limb length with sensory nerve conduction study parameters

Studied Parameter	r	P
Median Nerve:		
-SNAP amp (μv)	-0.017	0.8
-SCV (m/sec)	-0.033	0.7
Ulnar Nerve:		
-SNAP amp (μv)	-0.117	0.2
-SCV (m/sec)	0.12	0.2
Sural Nerve:		
-SNAP amp (μv)	0.083	0.4
-SCV (m/sec)	-0.098	0.3

SNAP amp: sensory nerve action potential amplitude, **μv:** microvolt, **SCV:** sensory conduction velocity, **m/sec:** meter per second.

Table (10): Correlation of body mass index (BMI) with motor nerve conduction study parameters

Studied Parameter	r	P
Median Nerve		
DML (msec)	**0.25***	**0.01***
D amp (mV)	-0.14	0.1
P amp (mV)	-0.21	0.05
MCV (m/sec)	-0.09	0.3
Ulnar Nerve		
DML (msec)	-0.11	0.3
Amp 1 (mV)	0.09	0.3
Amp 2 (mV)	0.02	0.8
Amp 3 (mV)	-0.19	0.1
MCV1 (m/sec)	0.16	0.1
MCV 2 (m/sec	0.07	0.6
Posterior Tibial Nerve		
DML (msec)	**0.25***	**0.01***
D amp (mV)	-0.03	0.8
P amp (mV)	-0.07	0.4
MCV (m/sec)	-0.06	0.6
Common Peroneal Nerve		
DML (msec)	0.19	0.08
D amp (mV)	0.16	0.1
P amp (mV)	0.09	0.4
MCV (m/sec)	-0.09	0.4

DML: distal motor latency, **msec:** millisecond, **D amp:** distal compound motor action potential (cMAP) amplitude, **mv:** millivolt, **P amp**: proximal cMAP amplitude, **MCV:** motor conduction velocity **m/sec:** meter per second. **Amp1:** distal cMAP amplitude at wrist stimulation, **Amp2:** cMAP amplitude at below elbow stimulation, **Amp3:** cMAP amplitude at above elbow stimulation.

Table (11): Correlation of body mass index (BMI) with F-M latencies

Studied Nerve	r	P
Median	**0.43****	**<0.001****
Ulnar	**0.42****	**<0.001****
Posterior Tibial	**0.46****	**0.001****

Table (12): Correlation of body mass index (BMI) with sensory nerve conduction study parameters

Studied Parameter	r	P
Median Nerve:		
-SNAP amp (μv)	0.042	0.6
-SCV (m/sec)	0.012	0.9
Ulnar Nerve:		
-SNAP amp (μv)	0.042	0.6
-SCV (m/sec)	0.012	0.9
Sural Nerve:		
-SNAP amp (μv)	0.05	0.6
-SCV (m/sec)	0.13	0.2

SNAP amp: sensory nerve action potential amplitude, **μv:** microvolt, **SCV:** sensory conduction velocity, **m/sec:** meter per second.

Discussion

Age-matched normal values for parameters of routine NCSs are either derived from studies on groups of healthy subjects or obtained from literature. [3] The majority of research studying standard norms of NCSs were based on non-Egyptian subjects. Therefore, we planned to study standard norms and the effect of certain factors (age, sex, height, limb length and body mass index) on routine nerve conduction studies among healthy individuals in Minia governorate.

Regarding **age**, DML has been shown to be significantly delayed with age in median, posterior tibial and common peroneal motor nerve conduction studies. F-M latency was also significantly prolonged with age in median, ulnar and posterior tibial nerves. Delay in DML and prolongation of F-M latency with age were in agreement with findings shown by Huang et al., (2009), Ortiz-Corredor et al., (2009) and Maher et al., (2013). [4, 5, 6] In sensory nerve conduction studies, SNAP amplitudes were significantly smaller in elderly during median and sural sensory nerve conduction studies. Moreover, sensory conduction velocity was significantly reduced in elderly in median sensory nerve conduction study. That was in agreement with the findings seen by Saeed and Akram (2008), Fujimaki et al., (2009) and Thakur et al., (2010). [7, 8, 9] SNAP amplitudes were more affected by age than cMAP amplitudes. That might be explained by the collateral sprouting in the muscle and the greater regeneration capacity of motor fiber than that of sensory fibers. [10]

Regarding **sex**, the studied parameters did not show significant differences in between males and females. That was in agreement with the findings given by Soudmand et al., (1982), Stetson et al., (1992), Shehab et al., (2001) and Saeed and Akram (2008).[11, 12, 13, 7]

Regarding the correlation between **height** and motor nerve conduction study parameters, the DML of median, posterior tibial and common peroneal nerves showed positive statistically significant correlation with height. That was in agreement with Thakur et al., (2011) who showed positive correlation between height and DML of most of motor nerves. [14] That could be explained by the tapering and poorer myelination at distal parts of the peripheral nerves, and being cooler. [15] Moreover, cMAP amplitude showed positive statistically significant correlation with height in ulnar, common peroneal and posterior tibial nerves. That was also, in agreement with Thakur et al., (2011) who found positive correlation between height and cMAP amplitudes in most of motor nerves.[14] In the other hand, MCV of the posterior tibial nerve showed negative statistically significant correlation with height. That was in agreement with Bodofsky et al., (2009) who presented the negative correlation between nerve conduction velocity and height. [16] And also, in agreement with Caress, (2007) who showed that this correlation is more evident in lower limbs.[15] Regarding the highly significant correlation between height and F-M latencies, that was in agreement with Huang et al., (2009).[4]

Regarding the correlation between **limb length** and routine nerve conduction study parameters, correlations were similar to those seen with height. But limb length may add value, as limb lengths varies in different individuals with the same height. So, with the limb index there is a narrower range of variability, and the influence of nerve length could be excluded. [17]

Regarding the **body mass index**, it showed positive statistically significant correlation with the DML of median and posterior tibial nerves and highly significant positive correlation with F-M latencies of median, ulnar and posterior tibial nerves. That was in agreement with Pawar et al., (2012). [18]

Conclusion

Studying the standard norms of routine nerve conduction studies is mandatory before examining patients with different types of neuropathies. The examiner must be aware by the effect of different factors especially age, height, limb length and body mass index on these variables.

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