JOURNAL OF
CONTEMPORARY MEDICINE

DOI:10.16899/jcm.1716267
J Contemp Med 2025;15(5):226-231

Original Article / Orijinal Araştırma

Effect of Surface Electrode Type on Sensory and Motor Nerve Conduction Study Findings: A Controlled Electrophysiological Study

Yüzeyel Elektrot Tipinin Duyusal ve Motor Sinir İletim Çalışması Bulguları Üzerindeki Etkisi: Kontrollü Elektrofizyolojik Bir Çalışma

Ismail Bayar[1], Elife Yarbaşar[1], Halit Fidancı[2], Halil Can Alaydın[2], Ahmet Yusuf Ertürk[2], Mehmet Yıldız[3]

[1]Clinical Neurophysiology Laboratory, Adana City Training and Research Hospital, University of Health Sciences, Adana, Türkiye
[2]Division of Clinical Neurophysiology, Department of Neurology, Adana City Training and Research Hospital, University of Health Sciences, Adana, Türkiye
[3]Department of Neurology, Adana City Training and Research Hospital, University of Health Sciences, Adana, Türkiye

Abstract

Aim: Individual characteristics, such as age, or technical factors, such as recording electrode characteristics, may influence nerve conduction study findings. This study aimed to investigate the effects of different surface electrode types on sensory and motor NCS findings and to evaluate their clinical interchangeability and impact on reference values.

Material and Method: This prospective study included 30 healthy volunteers. Sensory and motor NCSs of the median and ulnar nerves were performed using four surface electrode types: disposable pre-gelled adhesive electrodes (DPAE), cut-in-half DPAE (CDPAE), silver cup electrodes (SCE), and felt bar electrodes (FBE). Compound muscle action potential (CMAP) and Compound nerve action potential (CNAP) parameters—including latency, amplitude, duration, and negative area—were recorded. Sensory nerve conduction velocities (NCVs) were calculated based on onset and peak latencies.

Results: CMAP latency, amplitude, duration, and negative area, as well as CNAP amplitude and sensory NCV, varied significantly. In contrast, motor NCVs and F-wave latencies did not differ. CDPAE and SCE produced comparable results across most parameters. Reference values differed depending on the electrode type.

Conclusion: Surface electrode type has a significant impact on both motor and sensory NCS parameters. CDPAE and SCE appear to be clinically interchangeable. Given the variability in reference values, laboratories should generate electrode-specific normative data to ensure accurate interpretation and diagnosis in clinical neurophysiology.

Keywords: Electrodes, electrodiagnostic, nerve conduction studies

Öz

Amaç: Yaş gibi bireysel özellikler veya kayıt elektrodu özellikleri gibi teknik faktörler, sinir iletim çalışması (SİÇ) bulgularını etkileyebilir. Bu çalışmanın amacı, farklı yüzeyel elektrot tiplerinin duyusal ve motor SİÇ bulguları üzerindeki etkilerini araştırmak ve klinik olarak birbirlerinin yerine kullanılabilirliklerini ve referans değerler üzerindeki etkilerini değerlendirmektir.

Gereç ve Yöntem: Bu prospektif çalışmaya 30 sağlıklı gönüllü dahil edildi. Median ve ulnar sinirlerin duyusal ve motor SİÇ'leri dört farklı yüzeyel elektrot tipi kullanılarak yapıldı: tek kullanımlık, önceden jelle kaplı yapışkan elektrotlar (TYE), ikiye kesilmiş TYE (KTYE), gümüş kap elektrotlar (KE) ve keçe bar elektrotlar (KBE). Bileşik kas aksiyon potansiyeli (BKAP) ve bileşik sinir aksiyon potansiyeli (BSAP) parametreleri —latans, amplitüd, süre ve negatif alan dahil olmak üzere— kaydedildi. Duyusal sinir iletim hızları (SİH), başlangıç ve pik latanslara göre hesaplandı.

Bulgular: BKAP latansı, amplitüdü, süresi ve negatif alanı ile BSAP amplitüdü ve duyusal SİH anlamlı şekilde farklılık gösterdi. Buna karşın, motor SİH'ler ve F-dalga latansları farklılık göstermedi. KTYE ve KE, çoğu parametrede benzer sonuçlar verdi. Elektrot tipine göre referans değerler değişiklik gösterdi.

Sonuç: Yüzeyel elektrot tipi hem motor hem de duyusal SİÇ parametreleri üzerinde önemli bir etkiye sahiptir. KTYE ve KE klinik olarak birbirlerinin yerine kullanılabilir görünmektedir. Referans değerlerdeki değişkenlik göz önüne alındığında, laboratuvarlar doğru yorum ve tanı için elektrota özgü normatif veriler oluşturmalıdır.

Anahtar Kelimeler: Elektrotlar, elektrodiagnostik, sinir iletim çalışmaları

Corresponding *(İletişim)*: Halit Fidancı, Department of Neurology, Division of Clinical Neurophysiology, University of Health Sciences Adana City Training and Research Hospital, Adana, Türkiye
E-mail *(E-posta)*: dr.halitfidanci@gmail.com
Received *(Geliş Tarihi)*: 10.06.2025 **Accepted *(Kabul Tarihi)*:** 20.08.2025

INTRODUCTION

Nerve conduction studies (NCSs) are a fundamental component of electrodiagnostic testing, playing a critical role in the diagnosis of conditions such as entrapment neuropathies and polyneuropathies.[1-4] Compound muscle action potentials (CMAPs) and compound nerve action potentials (CNAPs) recorded during motor and sensory NCSs are obtained via recording electrodes.[1-6] While both surface and needle electrodes are commonly used, surface electrodes are generally preferred due to their noninvasive nature and ease of application, in contrast to the invasiveness and certain technical limitations of needle electrodes.[6]

NCS findings can be influenced by patient-related factors such as age and limb temperature, as well as technical parameters including band-pass filter settings, the distance between active and reference electrodes, and electrode material properties.[1,3,5-9] These factors may lead to inaccurate results or missed diagnoses. The choice of electrode may vary depending on the nerve being evaluated or the characteristics of the patient. While some laboratories routinely use bar electrodes, others prefer disk electrodes. In addition, adhesive electrodes may be preferred because they are disposable and offer advantages in terms of hygiene. Moreover, reference values for nerve conduction studies can differ according to the type of the electrode employed. Although bar and disk electrodes are more commonly used in research, adhesive electrodes may also have practical advantages. Accordingly, this study aimed to investigate the impact of different surface electrode types on NCS findings.

MATERIAL AND METHOD

The study was carried out with the permission of the University of Health Sciences Adana City Training and Research Hospital Ethics Committee (Date: 2025, Decision No: 12/473). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants.

Subjects

This prospective study was conducted between April and May 2025 in the Clinical Neurophysiology Laboratory of Adana City Training and Research Hospital, University of Health Sciences. The study population consisted of 30 healthy volunteers. Individuals with any of the following were excluded: (1) abnormalities on neurological examination, (2) clinical or electrophysiological findings suggestive of entrapment neuropathy in the upper extremities, (3) findings consistent with cervical radiculopathy or brachial plexopathy, (4) neurodegenerative disease, and (5) polyneuropathy or any condition that may cause polyneuropathy, such as diabetes mellitus.

Nerve Conduction Studies

Nerve conduction studies (NCSs) were performed by at least one clinical neurophysiologist and an electroneurophysiology technician, using a Cadwell Sierra Summit EMG unit (Cadwell Laboratories, Kennewick, WA, USA). All studies were conducted in accordance with established recommendations.[1,2] Examinations were performed only when the limb temperature exceeded 32°C; otherwise, the extremity was warmed. The bandpass filter settings were 20 Hz–10 kHz for motor NCSs and 20 Hz–2 kHz for sensory NCSs. Sensory and motor NCSs were applied supramaximally with surface metal electrodes. A medallion-shaped ground electrode was placed between the stimulation site and the active electrode. The surface electrodes used for recording included: disposable pre-gelled adhesive surface electrodes (DPAE) (23x34 mm, FIAB, Florence, Italy), reusable silver surface cup electrodes (SCE) (diameter: 10 mm, Ossamedikal, İstanbul, Türkiye), and reusable felt bar electrodes (FBE) (7x20 mm, Ossamedikal, İstanbul, Türkiye). In addition, DPAEs were cut in half to produce cut-in-half DPAEs (CDPAE), which were also used for recording. The DPAE was divided into two symmetrical parts at the midpoint, with careful attention to measurements. NCSs were performed in order of DPAE, CDPAE, SCE, and FBE. **Figure 1** illustrates the types of surface electrodes. The distance between the active and reference electrodes was 4 cm for all electrode types in both motor and sensory NCSs, consistent with the spacing used for the FBE. Distance measurements were taken from the midpoint of the electrodes. The locations of active and reference electrodes, as well as the stimulation sites for motor and sensory NCSs, were marked prior to the study. Conductive gel was applied for SCEs and physiological saline for FBEs. In motor NCSs, sweep speed and sensitivity were set at 5 ms/division and 2–5 mV/division, respectively; in sensory NCSs, 1 ms/division and 10 µV/division. Recordings were obtained from the abductor pollicis brevis and abductor digiti minimi muscles for the median and ulnar nerves, respectively. In motor NCSs, active and reference electrodes were placed following the belly–tendon montage principle. Stimulation sites for the median motor NCS were the wrist and elbow; for the ulnar motor NCS, the wrist, below-elbow, and above-elbow segments. The distance between the wrist stimulation point and the recording electrode was 5 cm. For the ulnar nerve, the below-elbow stimulation site was located 4 cm distal to the medial epicondyle, and the above-elbow site was 6 cm proximal. Motor conduction velocity was calculated using standard techniques. Compound muscle action potential (CMAP) amplitudes of the median and ulnar nerves were measured both peak-to-peak (P-P) and onset-to-peak (O-P). **Figure 2** shows CMAPs of the median nerve recorded using different types of electrodes. At least 10 F-waves were recorded for both the median and ulnar nerves, and the minimal F-wave latency was documented.

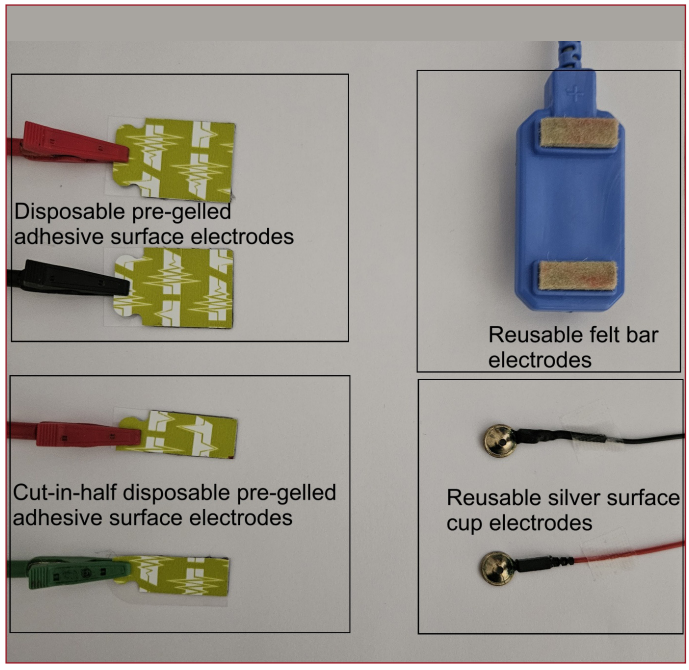

Figure 1. Types of surface electrodes used in the study

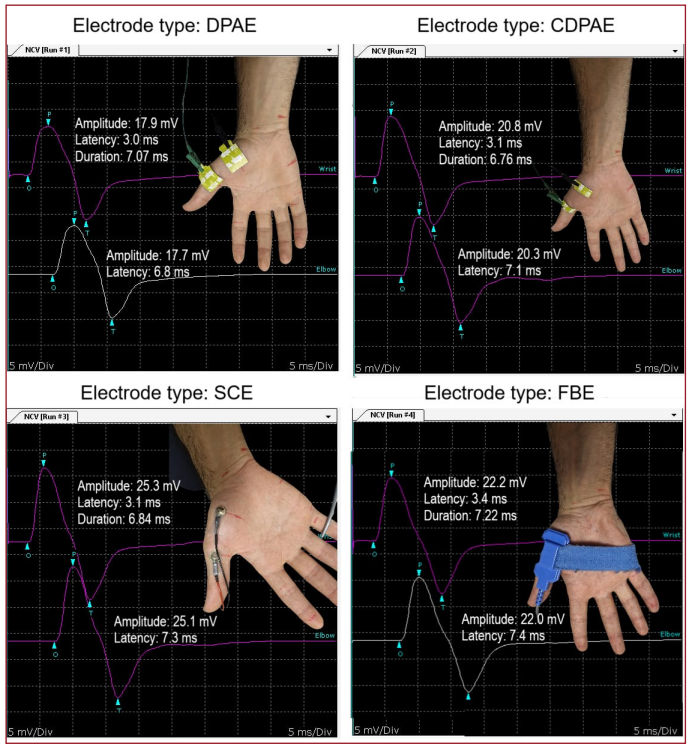

Figure 2. Median nerve CMAPs recorded with different surface electrodes in a representative individual

CMAP: compound muscle action potential, CDPAE: cut-in-half disposable pre-gelled adhesive electrode, DPAE: disposable pre-gelled adhesive electrode, FBE: felt bar electrode, SCE: silver cup electrode.

Median and ulnar sensory NCSs were applied antidromically. Electrodes for the median and ulnar nerves were placed on the 2nd and 5th fingers, respectively. The stimulation point was the wrist. Compound nerve action potential (CNAP) amplitude was measured P-P. The distance between the stimulation point and the recording electrode was 10-14 cm. Sensory nerve conduction velocity was calculated using both onset and peak latency.

Statistical analysis

Categorical variables were presented as counts and percentages (%), while numerical variables were expressed as mean±standard deviation (SD), median, and range. The Friedman test was used to compare dependent variables, and Bonferroni correction was applied for post-hoc analyses. Nerve conduction study (NCS) reference values were reported as mean±2 SD and 2.5th–97.5th percentiles.[10] Intraclass correlation coefficients (ICCs) were used to assess the consistency of nerve conduction study results obtained with different surface electrode types. ICC values were interpreted as follows: less than 0.5 indicated poor reliability, 0.5 to 0.75 indicated moderate reliability, 0.75 to 0.90 indicated good reliability, and greater than 0.90 indicated excellent reliability.[11] A p-value < 0.05 was considered statistically significant. All statistical analyses were performed using the SPSS version 22.0 software.

RESULTS

Sixteen participants (53.3%) were male. The mean age of the participants was 28.6±5.8 years (range: 18–44). The mean height, weight, and body mass index (BMI) were 169.0±8.9 cm (range: 152–190), 73.1±4.5 kg (range: 42–108), and 25.2±4.5 kg/m^2 (range: 16.7–33.9), respectively.

Table 1 presents the nerve conduction study (NCS) findings of the median and ulnar nerves obtained using different types of electrodes. **Table 2** shows the statistical results of overall and pairwise comparisons of NCS findings obtained using four different electrode types. **Table 3** presents the ICCs of nerve conduction study results obtained using CDPAE and SCE. **Table 4** shows the NCS reference values of the median and ulnar nerves obtained using different types of electrodes.

Table 3. Intraclass correlation coefficients of nerve conduction study findings obtained using CDPAE and SCE

Nerve conduction study	Intraclass correlation coefficient (Median / Ulnar nerve)
Distal CMAP latency ms	0.837 / 0.783
Distal CMAP Amplitude O-P mV	0.871 / 0.888
Distal CMAP Amplitude P-P mV	0.890 / 0.807
Distal CMAP duration ms	0.818 / 0.861
Negative area	0.910 / 0.877
Motor NCV forearm seg. m/s	0.706 / 0.531
Motor NCV elbow seg. m/s	/ 0.544
F-wave latency ms	0.806 / 0.836

CDPAE: cut-in-half disposable pre-gelled adhesive electrode, CMAP: compound muscle action potential, DPAE: disposable pre-gelled adhesive electrode, FBE: felt bar electrode, ICC: intraclass correlation coefficient, NCV: nerve conduction velocity, O–P: onset-to-peak, P–P: peak-to-peak, SCE: silver cup electrode. Reliability was assessed using ICCs.

Table 1. Comparison of nerve conduction study findings obtained using different surface electrodes

Median NCS	DPAE Mean±SD (median)	CDPAE Mean±SD (median)	SCE Mean±SD (median)	FBE Mean±SD (median)	P value
Distal CMAP latency (ms)	2.95±0.31 (3.00)	2.99±0.35 (3.00)	3.08±0.40 (3.05)	3.19±0.46 (3.20)	<0.001
Distal CMAP amplitude (mV, O-P)	9.55±2.61 (9.05)	10.28±2.52 (9.85)	10.38±2.58 (9.85)	8.71±2.47 (8.60)	<0.001
Distal CMAP amplitude (mV, P-P)	15.17±3.62 (14.35)	17.03±3.89 (16.45)	16.62±3.93 (15.55)	14.05±3.94 (14.70)	<0.001
Distal CMAP duration (ms)	5.83±0.65 (5.74)	5.71±0.58 (5.70)	5.85±0.71 (5.85)	6.03±0.80 (5.98)	0.005
Negative area	31.96±8.59 (31.77)	34.25±9.30 (34.04)	33.75±9.67 (31.14)	29.38±9.35 (29.06)	<0.001
Motor NCV forearm segment (m/s)	59.90±3.18 (60.00)	60.04±3.97 (60.00)	59.37±3.91 (59.50)	59.77±3.64 (60.50)	0.184
F-wave latency (ms)	25.33±1.69 (25.39)	25.38±1.57 (25.62)	25.77±1.84 (26.09)	25.85±1.71 (26.22)	0.116
CNAP amplitude (μV)	84.14±31.62 (73.65)	88.26±30.40 (85.40)	89.18±35.09 (85.40)	93.86±31.05 (90.85)	0.001
Sensory NCV (onset latency, m/s)	46.60±3.95 (46.50)	45.77±3.71 (45.00)	45.10±4.05 (45.50)	44.55±3.90 (45.00)	<0.001
Sensory NCV (peak latency, m/s)	62.75±5.16 (62.50)	60.57±4.45 (60.50)	58.93±4.83 (57.50)	57.33±4.87 (57.00)	0.001
Ulnar NCS					
Distal CMAP latency (ms)	2.28±0.27 (2.20)	2.39±0.32 (2.30)	2.40±0.37 (2.30)	2.45±0.36 (2.40)	0.003
Distal CMAP amplitude (mV, O-P)	9.66±2.09 (9.70)	9.91±2.32 (9.90)	9.66±2.52 (9.15)	9.53±2.48 (9.80)	0.151
Distal CMAP amplitude (mV, P-P)	15.44±3.22 (15.25)	16.55±3.39 (16.19)	16.09±3.90 (14.85)	15.33±3.85 (15.00)	0.001
Distal CMAP duration (ms)	5.88±0.84 (5.81)	5.80±0.69 (5.74)	5.79±0.68 (5.74)	5.89±0.80 (5.85)	0.157
Negative area	29.64±6.55 (30.05)	31.15±7.18 (30.98)	30.23±7.31 (29.03)	27.57±7.67 (26.74)	0.001
Motor NCV forearm segment (m/s)	64.43±3.72 (63.50)	64.00±4.41 (64.00)	64.20±4.90 (63.50)	62.47±5.16 (64.00)	0.038
Motor NVC elbow segment (m/s)	65.07±7.92 (64.50)	63.90±7.03 (64.00)	64.77±6.67 (65.00)	65.90±7.84 (67.00)	0.279
F-wave latency (ms)	25.42±1.78 (25.27)	25.88±1.92 (26.12)	26.05±1.97 (26.22)	25.37±3.12 (25.69)	0.047
CNAP amplitude (μV)	74.13±26.08 (68.55)	73.27±30.47 (66.55)	86.57±39.21 (77.05)	79.88±33.18 (74.00)	0.004
Sensory NCV (onset latency, m/s)	44.23±3.42 (44.00)	44.93±4.58 (45.00)	44.10±3.99 (43.50)	43.10±3.34 (42.50)	<0.001
Sensory NCV (peak latency, m/s)	61.07±3.82 (69.00)	58.73±4.04 (58.50)	58.77±5.54 (58.00)	57.07±4.59 (57.00)	0.188

CDPAE: cut-in-half disposable pre-gelled adhesive electrode, CMAP: compound muscle action potential, CNAP: compound nerve action potential, DPAE: disposable pre-gelled adhesive electrode, FBE: felt bar electrode, NCV: nerve conduction velocity, O–P: onset-to-peak, P–P: peak-to-peak, SCE: silver cup electrode, SD: standard deviation. Comparisons were made using the Friedman test.

Table 2. Pairwise comparison of nerve conduction study findings between different types of electrodes

Median / Ulnar NCS	Median / Ulnar NCS						
	P value	DPAE vs CDPAE	DPAE vs SCE	DPAE vs FBE	CDPAE vs SCE	CDPAE vs FBE	SCE vs FBE
Distal CMAP latency ms	<0.001 / 0.003	1.000 / 0.075	0.056 / 0.036	<0.001 / 0.019	0.167 / 1.000	<0.001 / 1.000	0.273 / 1.000
Distal CMAP Amplitude mV (O-P)	<0.001 / 0.151	0.098 / -	0.026 / -	0.882 / -	1.000 / -	0.001 / -	<0.001 / -
Distal CMAP Amplitude mV (P-P)	<0.001 / 0.001	<0.001 / 0.001	0.016 / 0.167	1.000 / 1.000	1.000 / 0.802	<0.001 / 0.008	<0.001 / 0.535
Distal CMAP duration ms	0.005 / -0.157	0.727 / -	1.000 / -	0.345 / -	0.167 / -	0.003 / -	1.000 / -
Negative area	<0.001 / 0.001	0.003 / 0.098	0.129 /1.000	1.000 / 0.658	1.000 / 0.658	<0.001 / <0.001	0.006 / 0.098
Motor NCV forearm seg. m/s	0.184 / 0.038	- / 1.000	- / 1.000	- / 0.086	- / 1.000	- / 0.167	- / 0.727
Motor NCV elbow seg. m/s	- / 0.279	- / -	- / -	- / -	- / -	- / -	- / -
F-wave latency ms	0.116 / 0.047	- / 0.147	- / 0.075	- / 0.386	- / 1.000	- / 1.000	- / 1.000
CNAP amplitude uV	0.001 / 0.004	0.431 / 0.189	0.431/0.003	<0.001 / 0.031	1.000 / 1.000	0.167 / 1.000	0.167 / 1.000
Sensory NCV (onset latency) m/s	<0.001 / <0.001	0.075 / 0.075	<0.001 / 0.075	<0.001 / 0.001	0.658 / 1.000	0.012 / 1.000	0.802 / 1.000
Sensory NCV (peak latency) m/s	0.001 / 0.188	0.481 / -	0.167 / -	0.002 / -	0.653 / -	0.345 / -	0.882 / -

CDPAE: cut-in-half disposable pre-gelled adhesive electrode, CMAP: compound muscle action potential, CNAP: compound nerve action potential, DPAE: disposable pre-gelled adhesive electrode, FBE: felt bar electrode, F-wave: F-wave latency, NCS: nerve conduction study, NCV: nerve conduction velocity, O–P: onset-to-peak, P–P: peak-to-peak, SCE: silver cup electrode, SD: standard deviation. Pairwise comparisons were performed using the Friedman test with Bonferroni correction ("-" indicates that no post-hoc comparison was performed because the Friedman test did not reveal a significant overall difference).

Table 4. Reference values for nerve conduction studies obtained using different surface electrodes

Median NCS	DPAE Reference value (2.5-97.5%)	CDPAE Reference value (2.5-97.5%)	SCE Reference value (2.5-97.5%)	FBE Reference value (2.5-97.5%)
CMAP latency ms	<3.57 (2.36-3.54)	<3.69 (2.41-3.75)	<3.88 (2.36-3.90)	<4.11 (2.36-4.15)
CMAP amplitude O-P mV				
CMAP amplitude P-P mV	>7.93 (10.41-23.47)	>9.25 (10.57-25.56)	>8.76 (11.61-26.07)	>6.17 (5.21-21.38)
Duration ms	<7.13 (4.83-7.09)	<6.87 (4.48-6.72)	<7.27 (4.48-7.28)	<7.63 (4.59-7.65)
NCV	>53.54 (55.00-66.45)	>52.10 (52.10-67.35)	>51.55 (52.00-66.45)	>52.49 (52.20-66.45)
F-wave latency	<28.71 (21.67-27.89)	<28.52 (22.38-28.18)	<29.45 (21.78-28.59)	<29.27 (23.19-28.59
CNAP amplitude	>20.9 (41.09-152.91)	>27.46 (43.77-157.41)	>19.00 (39.23-174.31)	>31.76 (47.76-160.26)
NCV peak	>38.70 (40.96-53.52)	>38.35 (40.00-53.45)	>37.00 (38.55-52.90)	>36.75 (38.00-52.00)
NCV onset	>52.43 (54.00-73.02)	>51.67 (54.00-68.90)	>49.27 (52.20-69.35)	>47.59 (50.00-67.25)
Ulnar NCS				
CMAP latency ms	<2.82 (2.00-2.84)	<3.03 (2.00-3.17)	<3.14 (2.00-3.27)	<3.17 (1.96-3.25)
CMAP amplitude PP mV	>9.00 (9.89-22.50)	>9.77 (10.56-24.07)	>8.29 (10.61-24.24)	>7.63 (6.87-22.96)
Duration	<7.56 (4.38-7.74)	<7.18 (4.58-7.12)	<7.15 (4.66-4.86)	<7.49 (4.31-7.34)
NCV forearm	>56.99 (58.76-72.25)	>55.18 (54.65-72.00)	>54.40 (55.00-74.45)	>52.15 (52.10-70.45)
NCV elbow	>49.23 (49.85-79.70)	>49.84 (48.20-75.90)	>51.43 (54.10-77.00)	>50.22 (49.10-78.35)
F-wave latency	<28.98 (21.98-28.24)	<29.72 (21.51-28.38)	<29.99 (22.22-28.86)	<31.61 (17.82-28.87
CNAP amplitude	>21.97 (35.73-124.09)	>12.33 (26.30-138.70)	>8.15 (37.99-181.62)	>3.52 (29.53-143.22)
NCV peak	>37.39 (38.55-50.00)	>35.77 (37.65-54.95)	>36.12 (38.00-50.90)	>36.42 (38.55-49.45)
NCV onset	>53.43 (55.00-67.90)	>50.65 (51.10-67.00)	>47.69 (49.10-67.45)	>47.89 (49.10-67.90)

CDPAE: cut-in-half disposable pre-gelled adhesive electrode, CMAP: compound muscle action potential, CNAP: compound nerve action potential, DPAE: disposable pre-gelled adhesive electrode, FBE: felt bar electrode, NCS: nerve conduction study, NCV: nerve conduction velocity, O–P: onset-to-peak, P–P: peak-to-peak, SCE: silver cup electrode, SD: standard deviation. References values were presented as mean±2 standard deviation and 2.5th-97th percentiles.

DISCUSSION

This study investigated the effects of different surface electrodes including DPAE, CDPAE, SCE, and FBE on NCSs. The results demonstrated that NCS findings may vary depending on the electrode type, although no significant differences were observed between SCE and CDPAE. Notably, CMAP latency, amplitude, duration, and negative area, as well as CNAP amplitude and sensory nerve conduction velocity (NCV), differed across electrode types. However, these parameters remained comparable between SCE and CDPAE. In contrast, motor NCV and F-wave latency were unaffected by electrode type.

Many individual and technical factors, such as extremity temperature, bandpass filter settings, and electrode characteristics, can influence NCS, potentially leading to misinterpretation.[1,3-5,8,9] For example, in small muscles, electrodes with a wide recording area may yield CMAPs with reduced amplitude.[8,9,12] Consistent with this, the present study found that CMAP amplitudes recorded using FBE and DPAE were lower than those obtained with CDPAE and SCE. One plausible explanation for this discrepancy is phase cancellation.[8,9,12] DPAE and FBE may capture more widespread electrical potentials, and the reference electrode may not be completely restricted to the tendon, thereby increasing the likelihood of phase cancellation. In contrast, CDPAE and SCE are more precisely positioned over the tendon, which likely minimizes this effect. This phenomenon is particularly prominent in small muscles, such as the abductor pollicis brevis or abductor digiti quinti, which were evaluated in this study, whereas it appears to be less pronounced in larger muscles.[8,9,12]

Another contributing factor may be the limited conformity of the FBE to the muscle surface. When greater pressure is applied to the electrodes, their proximity to the muscle improves, resulting in higher CMAP amplitudes, whereas insufficient contact may lead to reduced recordings.[5,13] In contrast to the CMAP findings, CNAP amplitudes were lower with DPAE compared to SCE and FBE. This, too, may be attributed to phase cancellation, as the adhesive nature of DPAE allows it to capture more signal, which in turn increases the risk of phase cancellation.[8,9,12] FBE, while less conformable to the finger due to its rigidity, may still record a consistent signal from the contact points it maintains.

Motor NCVs and F-wave latencies did not differ significantly between electrodes. This is expected, as electrode-related effects on NCS are likely limited when assessing the entire nerve. However, differences in distal CMAP latencies may reflect more localized influences, such as the neuromuscular junction or short nerve segment. The distal CMAP latencies of the median and ulnar nerves obtained with DPAE were shorter than those recorded with FBE, and the ulnar CMAP latency obtained with DPAE was also shorter than that obtained with SCE. This may be related to electrode size. Since latency is measured from the stimulation site to the midpoint of the recording electrode, signals reaching the edges of larger electrodes may appear earlier, resulting in shorter latencies. Limited contact of the FBE with the skin may also contribute. Similar findings were noted in sensory NCV, especially in onset latencies, with DPAE yielding faster values likely for the same reasons. In a study comparing ring electrodes and disposable disk electrodes in median sensory NCS, no significant differences in findings were observed.[14] Similarly, the current study found comparable results between CDPAE and SCE. Just as ring and disposable disk electrodes can be used interchangeably, CDPAE and SCE may also be used interchangeably; however, this conclusion should be confirmed by further studies.

This study found that reference values varied depending on the type of electrode used. This finding suggests that if the type of electrode used to establish reference values differs from the electrode used in the neurophysiology laboratory, it may lead to misdiagnosis or missed diagnoses. Therefore, as consistently recommended, each laboratory should establish its own NCS reference values; alternatively, if reference values from other sources are used, the same methods and technical conditions under which those values were originally obtained must also be applied during routine testing.[2,4,5,15,16] Another important finding was the absence of significant differences in NCS parameters between CDPAE and SCE. The ICC of CDPAE and SCE indicated good reliability across most NCS measurements. This suggests that CDPAE and SCE may be used interchangeably. Moreover, the use of CDPAE may offer economic advantages, as a single DPAE is typically used per patient, while one DPAE can serve two patients when cut and used as CDPAE. Another important advantage of adhesive electrodes is that they are disposable and hygienic, which helps prevent the transmission of infections through the electrode.

This study had several limitations. First, only young healthy individuals were included. Similar studies involving patient populations or elderly individuals may yield different and potentially interesting results.[7] The study findings may also have been influenced by the sample size. Additionally, the impact of body mass index on NCS findings may be a potential limitation.[17] Another limitation was the possibility that the FBE, despite being securely fixed, may have loosened during the procedure, potentially affecting the results obtained with it. Although the stimulation, active, and reference electrode placement points were marked, electrodes may not have been positioned at exactly the same locations for each electrode type, or stimulation may not have been applied from precisely the same point. The effect of the adhesive electrodes used in this study on NCS findings remains open to discussion. Limitations may include the skin area where the electrodes were placed, the duration of adhesion, and the possibility that the DPAE was not divided into two equal parts. Despite these limitations, the study also had notable strengths. Various NCS findings

were evaluated, including CMAP amplitudes calculated using both onset-to-peak and peak-to-peak methods, the negative area and duration of CMAP, and sensory NCV values derived from onset and peak latencies. Detailed information was obtained regarding the interchangeability of different electrode types and their effects on NCS findings. These results provide a basis for further studies on this subject using various electrodes. We believe that confirming the present findings in larger populations and in studies employing different electrode types would make a valuable contribution to this field.

CONCLUSION

This study demonstrates that the type of surface electrode used can significantly affect multiple motor and sensory NCS findings, including CMAP latency, amplitude, duration, negative area, CNAP amplitude, and sensory NCV. While motor NCV and F-wave latency were not influenced by electrode type, differences in distal latency and amplitude suggest that electrode size, contact quality, and recording area can substantially impact results. Notably, CDPAE and SCE yielded comparable findings, supporting their interchangeable use in clinical practice. The observed variability in reference values across different electrodes underlines the importance of establishing laboratory-specific normative data to avoid misdiagnosis or missed diagnoses. Despite certain limitations, including a homogenous study population and the possibility of slight inconsistencies in electrode placement, this study provides important insights into optimizing electrode selection in routine NCS practice.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of the University of Health Sciences Adana City Training and Research Hospital Ethics Committee (Date: 2025, Decision No: 12/473).
Informed Consent: Written informed consent was obtained from all participants prior to enrollment in the study.
Referee Evaluation Process: Externally peer-reviewed.
Conflict of Interest Statement: The authors have no conflicts of interest to declare.
Financial Disclosure: The author declared that this study has received no financial support.
Author Contributions: All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

REFERENCES

1. Stålberg E, van Dijk H, Falck B, et al. Standards for quantification of EMG and neurography. Clin Neurophysiol 2019;130(9):1688-729.
2. Chen S, Andary M, Buschbacher R, et al. Electrodiagnostic reference values for upper and lower limb nerve conduction studies in adult populations. Muscle Nerve 2016;54(3):371-7.
3. Tavee J. Nerve conduction studies: Basic concepts. Handb Clin Neurol 2019;160:217-24.
4. Tankisi H, Burke D, Cui L, et al. Standards of instrumentation of EMG. Clin Neurophysiol 2020;131(1):243-58.
5. Koo YS, Cho CS, Kim BJ. Pitfalls in Using Electrophysiological Studies to Diagnose Neuromuscular Disorders. J Clin Neurol 2012;8(1):1-14.
6. Wilbourn AJ. Sensory nerve conduction studies. J Clin Neurophysiol 1994;11(6):584-601.
7. Rivner MH, Swift TR, Malik K. Influence of age and height on nerve conduction. Muscle Nerve 2001;24(9):1134-41.
8. Jonas D, Bischoff C, Conrad B. Influence of different types of surface electrodes on amplitude, area and duration of the compound muscle action potential. Clin Neurophysiol 1999;110(12):2171-5.
9. Van Dijk JG, Tjon-a-Tsien A, van der Kamp W. CMAP variability as a function of electrode site and size. Muscle Nerve 1995;18(1):68-73.
10. Dorfman LJ, Robinson LR. AAEM minimonograph #47:normative data in electrodiagnostic medicine. Muscle Nerve 1997;20:4-14.
11. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med 2016;15(2):155-63.
12. Barkhaus PE, Periquet MI, Nandedkar SD. Influence of the surface EMG electrode on the compound muscle action potential. Electromyogr Clin Neurophysiol 2006;46(4):235-9.
13. Ven AA, Van Hees JG, Stappaerts KH. Effect of size and pressure of surface recording electrodes on amplitude of sensory nerve action potentials. Muscle Nerve 2004;30(2):234-8.
14. Athar P, Jilani A, Nguyen TT. Comparison of ring versus disposable disk electrodes in recording antidromic sensory median nerve conduction study for diagnosis of carpal tunnel syndrome. J Clin Neurophysiol 2013;30(4):428-30.
15. Pandit A, Pattnaik S, Biswas S, Naik BN. Normative value of f-wave minimum latency in a tertiary care center in eastern India. Neurol India 2025;73(3):469-73.
16. Dillingham T, Chen S, Andary M, et al. Establishing high-quality reference values for nerve conduction studies: A report from the normative data task force of the American Association Of Neuromuscular & Electrodiagnostic Medicine. Muscle Nerve 2016;54(3):366-70.
17. Buschbacher RM. Body mass index effect on common nerve conduction study measurements. Muscle Nerve 1998;21(11):1398-404.