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Original Article

Clinical and Electrophysiological Evaluation of Peripheral Nervous System Involvement in Elderly Individuals: A Comparative Cross-Sectional Study

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ABSTRACT

Background: Aging is associated with structural and functional alterations in the peripheral nervous system (PNS), predisposing elderly individuals to neuropathic disorders. Distinguishing physiological age-related changes from pathological neuropathy remains clinically challenging, particularly in the presence of metabolic comorbidities.

Objective: To evaluate the clinical and electrophysiological characteristics of peripheral nervous system involvement in elderly individuals and to determine independent predictors and diagnostic accuracy of electrophysiological parameters.

Methods: This hospital-based cross-sectional comparative study included 200 elderly participants aged ≥60 years, comprising 100 individuals with clinical features suggestive of peripheral neuropathy (disease group) and 100 apparently healthy controls. Detailed neurological examination and standardized nerve conduction studies were performed, including motor and sensory assessments of median, ulnar, tibial, peroneal, sural, and superficial peroneal nerves. Parameters recorded included distal latency, conduction velocity, CMAP amplitude, SNAP amplitude, and F-wave latency. Multivariate logistic and linear regression analyses were conducted to identify independent predictors. Receiver operating characteristic (ROC) curve analysis, DeLong testing, and integrated discrimination improvement (IDI) were performed to assess diagnostic performance.

Results: The disease group demonstrated significantly prolonged distal latency, reduced conduction velocity, and lower CMAP and SNAP amplitudes compared to controls ($p < 0.001$). Axonal neuropathy was the predominant electrophysiological pattern. Diabetes mellitus, increasing age, higher BMI, and longer symptom duration were independent predictors of electrophysiological abnormality. Sural SNAP amplitude showed the highest individual diagnostic accuracy (AUC = 0.86). A combined multivariate model integrating clinical and electrophysiological variables significantly improved discrimination (AUC = 0.93; $p < 0.01$ by DeLong test) and demonstrated meaningful improvement in risk classification.

Conclusion: Peripheral nerve dysfunction in elderly individuals is strongly associated with metabolic risk factors in addition to physiological aging. Sensory nerve parameters, particularly sural SNAP amplitude, provide sensitive diagnostic markers. Integration of clinical and electrophysiological variables enhances diagnostic precision and supports individualized risk stratification in geriatric neurological care.

Keywords: Peripheral neuropathy; Elderly population; Nerve conduction studies; Sural SNAP amplitude; Axonal neuropathy; Diagnostic modeling; Predictive risk score.

INTRODUCTION

The peripheral nervous system (PNS) plays a vital role in maintaining sensory perception, motor coordination, reflex activity, and autonomic regulation, thereby ensuring functional independence and effective interaction with the environment. With advancing age, structural and physiological alterations occur throughout the nervous system, including peripheral nerves and neuromuscular junctions. These changes contribute to declining nerve conduction efficiency, reduced neuromuscular performance, and increased susceptibility to neuropathic disorders. As global life expectancy rises and the proportion of elderly individuals continues to grow, disorders of the peripheral nervous system have emerged as a significant public health concern due to their impact on mobility, balance, gait stability, and overall quality of life in older adults [1,2].

Physiological aging is characterized by progressive neuronal loss, axonal degeneration, segmental demyelination, and reduced regenerative capacity of peripheral nerves. Morphological studies have demonstrated a decrease in nerve fiber density, reduction in axonal diameter, thinning of myelin sheath, and compromised microvascular supply to peripheral nerves in elderly individuals. These alterations result in slowing of nerve conduction velocity, prolongation of distal latencies, and reduction in action potential amplitudes [3,4]. Although such changes may initially remain subclinical, they predispose elderly individuals to symptomatic peripheral neuropathies, especially in the presence of comorbid conditions such as diabetes mellitus, hypertension, chronic kidney disease, thyroid dysfunction, nutritional deficiencies, and metabolic disorders [5].

Peripheral neuropathy is one of the most common neurological disorders affecting the elderly population. Epidemiological studies indicate that approximately 15–30% of individuals above 60 years exhibit clinical or electrophysiological evidence of peripheral nerve dysfunction [6,7]. Clinical manifestations range from subtle sensory disturbances, paresthesias, and diminished vibration sense to overt motor weakness, gait instability, autonomic dysfunction, and increased risk of falls. These impairments significantly compromise functional independence and are associated with increased morbidity, disability, and healthcare utilization among older adults [8]. Early recognition of peripheral nerve involvement is therefore essential to prevent complications such as falls, pressure sores, chronic pain syndromes, and loss of autonomy.

Electrophysiological evaluation, particularly nerve conduction studies (NCS) and electromyography (EMG), provides an objective and quantitative assessment of peripheral nerve function. Nerve conduction studies measure parameters such as distal latency, conduction velocity, compound muscle action potential (CMAP) amplitude, sensory nerve action potential (SNAP) amplitude, and F-wave latency. These parameters allow differentiation between axonal and demyelinating neuropathies, identification of focal versus generalized nerve involvement, and assessment of severity [9]. In elderly individuals, electrophysiological testing is especially valuable because clinical findings may be subtle or confounded by age-related musculoskeletal changes, polypharmacy, or coexisting systemic illnesses [10].

Interpretation of electrophysiological findings in elderly individuals requires careful consideration of age-related normative variations. Several studies have demonstrated that nerve conduction parameters vary with age, height, sex, and limb temperature. Progressive reduction in conduction velocity and sensory amplitudes, particularly in distal lower limb nerves such as the sural and peroneal nerves, has been documented with advancing age [11–13]. These changes reflect cumulative axonal loss and altered myelination rather than overt pathological neuropathy. Therefore, distinguishing physiological aging from disease-related neuropathy remains a diagnostic challenge.

In addition to motor and sensory fibers, autonomic nerve fibers are also affected by aging. Autonomic dysfunction may manifest as orthostatic hypotension, impaired cardiovascular reflexes, altered thermoregulation, gastrointestinal dysmotility, and genitourinary disturbances. Such involvement often remains clinically unrecognized until advanced stages. Comprehensive electrophysiological assessment, when combined with autonomic testing, facilitates early detection of subclinical involvement and enables timely intervention [14,15].

The elderly population is particularly vulnerable to multiple etiological factors contributing to peripheral nerve dysfunction. Metabolic derangements, chronic alcohol use, nutritional deficiencies, drug-induced neurotoxicity, paraneoplastic syndromes, autoimmune disorders, and chronic systemic illnesses may exacerbate age-related nerve degeneration [16]. Moreover, age-associated decline in renal and hepatic function may increase susceptibility to medication-induced neuropathy. Thus, differentiating age-related physiological changes from pathological neuropathies necessitates thorough clinical evaluation supported by detailed electrophysiological assessment.

Despite the growing burden of peripheral nervous system disorders among elderly individuals, data from developing countries regarding electrophysiological profiles in this age group remain limited. Most available normative references are derived from younger populations or Western cohorts, which may not be directly applicable to elderly individuals in different ethnic, nutritional, and socioeconomic settings [17]. Regional variations in comorbidities, occupational exposures, and healthcare access further underscore the need for locally generated evidence.

A systematic clinical and electrophysiological evaluation of peripheral nerve function in elderly individuals provides valuable insights into the spectrum, distribution, and severity of nerve involvement. Such studies help establish age-appropriate reference values, improve diagnostic accuracy, and facilitate differentiation between physiological and pathological processes [18]. Early detection and appropriate management of peripheral nerve dysfunction can preserve mobility, reduce disability, and enhance quality of life in the aging population.

In view of the rapidly increasing elderly population and the substantial functional consequences of peripheral nerve dysfunction, comprehensive evaluation using clinical examination and electrophysiological techniques assumes considerable importance. The present study was therefore undertaken to assess the clinical and electrophysiological characteristics of peripheral nervous system involvement in elderly individuals and to compare findings with apparently healthy age-matched controls, thereby contributing to improved diagnostic and preventive strategies in geriatric neurological care.

MATERIALS AND METHODS

Study Design: This study was designed as a hospital-based cross-sectional comparative observational study conducted to evaluate and compare the clinical and electrophysiological characteristics of peripheral nervous system involvement in elderly individuals.

Study Setting: The study was carried out in the Department of Physiology, Malwanchal University, in collaboration with the concerned clinical departments of the affiliated teaching hospital.

Study Duration: The study was conducted over a period of twelve months after obtaining approval from the Institutional Ethics Committee.

Study Population: The study population comprised elderly individuals aged 60 years and above attending the outpatient and inpatient departments of the affiliated teaching hospital during the study period.
Participants were categorized into two groups:

- **Disease Group (Cases):** Elderly individuals with clinical features suggestive of peripheral nervous system involvement
- **Control Group:** Apparently healthy elderly individuals without clinical evidence of peripheral nervous system involvement

Sample Size Calculation: The sample size was calculated for comparison of two independent proportions using previously published electrophysiological data. The proportion of electrophysiological abnormalities in elderly individuals with peripheral nervous system involvement (P_1) was assumed to be 0.65, and in apparently healthy elderly individuals (P_2) was assumed to be 0.40.
Using the formula for comparison of two independent proportions:

$$n = \frac{(Z_{\alpha/2} + Z_{\beta})^2 [P_1(1-P_1) + P_2(1-P_2)]}{(P_1 - P_2)^2}$$

Where:

- ($Z_{\alpha/2}$ = 1.96) (95% confidence level)
- (Z_{β} = 1.28) (90% power)
- (P_1 = 0.65)
- (P_2 = 0.40)

The calculated minimum sample size was **79 participants per group**.
Considering a 10% contingency for incomplete data and non-cooperation, the final sample size was rounded to:

- **100 participants in the disease group**
- **100 participants in the control group**

Total sample size = **200 elderly participants**

Sampling Technique: A consecutive sampling technique was adopted. All eligible elderly individuals attending the hospital during the study period and fulfilling inclusion criteria were recruited consecutively until the required sample size in each group was achieved.

Eligibility Criteria

Inclusion Criteria

- Age ≥ 60 years
- Both male and female participants
- Willingness to provide written informed consent
- Elderly individuals with or without symptoms suggestive of peripheral nervous system involvement

Exclusion Criteria

- History of acute neurological illness (e.g., stroke, acute neuropathy)
- Known neuromuscular junction disorders
- Primary myopathies
- Severe cognitive impairment interfering with cooperation
- Critically ill patients
- Limb amputations or conditions interfering with nerve conduction studies

Data Collection Procedure: After obtaining Institutional Ethics Committee approval, eligible participants were enrolled following written informed consent.

A pre-designed and pre-tested case record form was used to collect:

- Demographic details (age, sex, residence, socioeconomic status)
- Detailed medical history (duration and nature of neurological symptoms)
- History of comorbidities (diabetes mellitus, hypertension, chronic kidney disease, thyroid disorders)
- Lifestyle factors (alcohol consumption, smoking)
- Drug history
- Nutritional status

Clinical Assessment: A comprehensive general physical examination was performed, followed by detailed neurological evaluation including:

Motor Examination

- Muscle bulk
- Muscle tone
- Muscle power (graded using Medical Research Council scale)
- Deep tendon reflexes

Sensory Examination

- Pain sensation
- Temperature sensation
- Light touch
- Vibration sense
- Joint position sense

Autonomic Assessment

- Postural dizziness
- Bowel or bladder disturbances
- Sweating abnormalities

Based on clinical findings, participants were categorized into disease and control groups.

Electrophysiological Assessment: All participants underwent nerve conduction studies (NCS) in the Neurophysiology Laboratory under standardized laboratory conditions using a calibrated electromyography and nerve conduction system. Room temperature was maintained between 24–26°C, and limb temperature was monitored to minimize variability.

Motor Nerve Conduction Studies

Motor nerve conduction studies were performed on:

- Median nerve
- Ulnar nerve
- Tibial nerve
- Peroneal nerve

Parameters recorded:

- Distal motor latency (DML)

- Compound muscle action potential (CMAP) amplitude
- Motor conduction velocity
- F-wave latency (where applicable)

Sensory Nerve Conduction Studies
Sensory nerve conduction studies were performed on:
- Median nerve
- Ulnar nerve
- Sural nerve
- Superficial peroneal nerve

Parameters recorded:
- Sensory nerve action potential (SNAP) amplitude
- Sensory conduction velocity
- Distal sensory latency

All recordings were obtained using surface electrodes and standardized stimulation protocols.

Classification of Neuropathy
Based on electrophysiological findings, neuropathy was classified as:
- **Axonal neuropathy:** Reduced CMAP/SNAP amplitude with relatively preserved conduction velocity
- **Demyelinating neuropathy:** Markedly slowed conduction velocity, prolonged distal latency, prolonged F-wave latency
- **Mixed neuropathy:** Features of both axonal loss and demyelination

Severity was graded based on amplitude reduction and conduction velocity changes.

Outcome Measures
Primary Outcome:
- Pattern and extent of peripheral nervous system involvement based on electrophysiological parameters

Secondary Outcomes:
- Correlation between clinical findings and electrophysiological abnormalities
- Distribution and severity of nerve involvement
- Association between risk factors and electrophysiological findings

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using appropriate statistical software. Continuous variables were expressed as mean ±standard deviation. Categorical variables were expressed as frequency and percentage. Independent t-test was used to compare means between groups. Chi-square test was applied for categorical comparisons. Correlation analysis was performed to assess association between clinical and electrophysiological parameters. A p-value < 0.05 was considered statistically significant.

RESULTS
A total of 200 elderly participants were included (100 disease group, 100 controls). The mean age of the disease group was slightly higher than controls, though not statistically significant. Diabetes mellitus and higher BMI were significantly more prevalent in the disease group ($p < 0.05$).(Table 1)

Table 1: Baseline Clinical Characteristics of Study Participants

Variable	Disease (n=100)	Control (n=100)	p-value
Age (years)	68.4 ± 6.2	66.9 ± 5.8	0.08
Male (%)	58	55	0.67
Diabetes (%)	42	18	<0.001*
Hypertension (%)	48	29	0.006*
BMI (kg/m²)	26.8 ± 3.4	24.9 ± 2.9	0.002*

Clinical and Electrophysiological Comparison
Participants in the disease group demonstrated significantly higher prevalence of sensory deficits, diminished ankle reflexes, and reduced vibration sense ($p < 0.001$). Motor and sensory nerve conduction parameters showed significant differences between groups. Distal motor latency was prolonged and conduction velocity was reduced in the disease

group. CMAP and SNAP amplitudes were significantly lower, indicating predominant axonal involvement. Lower limb nerves showed greater impairment than upper limb nerves.(Table 2)

Table 2: Comparison of Motor and Sensory Nerve Conduction Parameters

Parameter	Disease	Control	p-value
Median DML (ms)	4.8 ± 0.7	3.9 ± 0.5	<0.001*
Median CV (m/s)	46.2 ± 4.3	52.8 ± 3.9	<0.001*
Median CMAP (mV)	5.1 ± 1.8	7.4 ± 2.0	<0.001*
Tibial CV (m/s)	39.6 ± 5.1	46.9 ± 4.4	<0.001*
Sural SNAP (μV)	6.8 ± 3.4	14.2 ± 4.1	<0.001*
Sural CV (m/s)	36.4 ± 4.8	44.7 ± 4.2	<0.001*

Pattern of Neuropathy

Among the disease group, axonal neuropathy was the predominant electrophysiological pattern, followed by mixed and demyelinating types.(Table 3)

Table 3: Electrophysiological Pattern of Neuropathy (Disease Group)

Pattern	Frequency	Percentage
Axonal	64	64%
Demyelinating	18	18%
Mixed	18	18%

Multivariate Predictors of Electrophysiological Abnormality

Logistic regression analysis identified diabetes mellitus, increasing age, higher BMI, and longer duration of symptoms as independent predictors of electrophysiological abnormality.

Multiple linear regression demonstrated that age, diabetes, BMI, and symptom duration were independently associated with reduced sural SNAP amplitude (Adjusted $R^2 = 0.45$).(Table 4)

Table 4: Multivariate Regression Analysis

A. Logistic Regression (Outcome: Electrophysiological Abnormality)

Variable	Adjusted OR	95% CI	p-value
Age	1.08	1.02–1.14	0.006*
Diabetes	3.42	1.78–6.57	<0.001*
BMI	1.74	1.01–3.02	0.04*
Duration >2 years	2.63	1.39–4.98	0.003*

B. Linear Regression (Outcome: Sural SNAP)

Variable	β	p-value
Age	-0.31	<0.001*
Diabetes	-3.84	<0.001*
BMI	-0.27	0.01*
Duration	-1.42	0.009*

Adjusted $R^2 = 0.45$

Diagnostic Accuracy and Predictive Modeling

ROC curve analysis showed that sural SNAP amplitude had the highest individual diagnostic accuracy (AUC = 0.86). A combined multivariate model integrating clinical and electrophysiological variables significantly improved discrimination (AUC = 0.93, $p < 0.01$ by DeLong test). Integrated discrimination improvement (IDI) confirmed superior risk stratification with the combined model.(Table 5,6)

Table 5: ROC Curve Analysis and Model Comparison

Model	AUC (95% CI)	Sensitivity	Specificity	p-value
Sural SNAP	0.86 (0.80–0.92)	82%	79%	<0.001
Tibial CV	0.81 (0.74–0.88)	78%	73%	<0.001
Combined Model	0.93 (0.89–0.97)	88%	85%	<0.001

DeLong Test: Combined vs Sural SNAP → p = 0.01*

Table 6: Risk Reclassification and Predictive Score

A. Integrated Discrimination Improvement

Comparison	IDI	p-value
Combined vs Sural SNAP	0.11	0.002*

B. Predictive Model Formula

$$Logit(P) = -6.42 + (0.07 \times Age) + (1.23 \times Diabetes) + (0.05 \times BMI) + (0.81 \times Duration) - (0.28 \times SuralSNAP)$$

Combined Model AUC (bootstrap corrected): 0.91.

DISCUSSION

The present study provides a comprehensive clinical and electrophysiological evaluation of peripheral nervous system involvement in elderly individuals and integrates advanced predictive modeling to enhance diagnostic precision. The findings demonstrate significantly higher electrophysiological abnormalities in elderly individuals with clinical features of neuropathy compared to age-matched controls. Importantly, sensory nerve parameters—particularly sural SNAP amplitude—emerged as the most sensitive markers of peripheral nerve dysfunction.

Age-Related Peripheral Nerve Changes

Our findings confirm that advancing age is independently associated with electrophysiological abnormalities. Multivariate regression demonstrated that each incremental year of age significantly increased the odds of neuropathy. This aligns with earlier observations that age-related axonal loss, myelin thinning, and microvascular compromise contribute to slowed conduction velocity and reduced amplitudes [3,4]. Previous neurophysiological studies have also demonstrated progressive decline in sensory nerve amplitudes with aging, particularly in distal lower limb nerves [11–13].

Importantly, the regression model indicates that aging alone does not fully explain neuropathic changes; metabolic and modifiable risk factors significantly contribute to nerve dysfunction.

Predominance of Axonal Neuropathy

The majority of cases in our study demonstrated an axonal pattern of neuropathy. This is consistent with prior reports suggesting that distal symmetric axonal polyneuropathy is the most common form of neuropathy in elderly populations [19-20]. Axonal degeneration is believed to reflect cumulative metabolic, ischemic, and oxidative stress effects over time. The greater involvement of lower limb sensory nerves supports the "length-dependent" dying-back neuropathy model described in metabolic and toxic neuropathies [21,22]. Our findings reinforce the concept that distal sensory fibers are particularly vulnerable in aging.

Independent Predictors: Role of Metabolic Factors

Logistic regression analysis identified diabetes mellitus, increasing BMI, and longer symptom duration as independent predictors of electrophysiological abnormality. Diabetes demonstrated the strongest association (AOR > 3), highlighting its critical contribution to peripheral nerve degeneration in elderly individuals. These findings are concordant with literature describing diabetes as the leading cause of distal symmetric polyneuropathy [23]. Chronic hyperglycemia promotes microvascular injury, oxidative stress, and axonal degeneration. Furthermore, higher BMI independently predicted neuropathy, supporting previous evidence that metabolic syndrome components contribute to peripheral nerve

dysfunction [24]. The linear regression model demonstrated that age, diabetes, BMI, and symptom duration independently predicted reduced sural SNAP amplitude, explaining 45% of variability. This indicates moderate-to-strong predictive strength and reinforces the multifactorial etiology of neuropathy in elderly populations.

Diagnostic Accuracy: Superiority of Sensory Parameters

ROC curve analysis revealed that sural SNAP amplitude had the highest individual diagnostic accuracy (AUC = 0.86), indicating good discriminative ability. Sensory nerve parameters outperformed motor parameters, emphasizing early sensory fiber involvement. The combined multivariate predictive model significantly improved discrimination (AUC = 0.93), achieving excellent diagnostic performance. DeLong testing confirmed statistically superior AUC compared to single-parameter models. Furthermore, integrated discrimination improvement (IDI) analysis demonstrated meaningful enhancement in risk classification (11–16%). These findings highlight that integrating clinical and electrophysiological parameters provides substantially improved diagnostic precision compared to isolated nerve conduction measurements. To our knowledge, few previous studies in elderly populations have applied combined predictive modeling with ROC, DeLong testing, and IDI analysis. Therefore, this study advances the field by providing a statistically robust, clinically applicable risk prediction framework.

Clinical Implications

The identification of sural SNAP amplitude as the strongest electrophysiological marker has important clinical implications:

1. Distal sensory testing should be prioritized in elderly individuals.
2. Early detection of reduced SNAP amplitude may allow timely intervention.
3. Integration of metabolic risk factors into assessment improves prediction accuracy.

The developed predictive score and nomogram provide a practical tool for individualized risk estimation. Such tools are increasingly recommended in precision medicine approaches and geriatric neurology.

Our findings are consistent with Bouche et al. [20], who demonstrated age-related conduction slowing, and Nutan et al. [25,26], who reported that age alone explains limited variance in nerve conduction abnormalities. The present study expands on these findings by demonstrating that metabolic variables significantly enhance predictive power.

Similarly, Taksande et al. [24] reported that age and BMI negatively influence conduction velocity and amplitude. Our regression results corroborate this observation and quantify their independent contribution.

Limitations

Despite its strengths, certain limitations should be acknowledged:

- Single-center hospital-based design
- Cross-sectional nature limits causal inference
- Lack of external validation cohort
- Autonomic testing not extensively quantified

Future multicenter longitudinal studies are needed to validate the predictive model and assess long-term outcomes.

CONCLUSION

Peripheral nervous system involvement is common among elderly individuals and is influenced by both physiological aging and modifiable metabolic risk factors. The present study demonstrates that elderly individuals with clinical symptoms exhibit significantly greater electrophysiological abnormalities compared to age-matched controls. Sensory nerve parameters, particularly sural SNAP amplitude, emerged as the most sensitive markers of peripheral nerve dysfunction. Multivariate regression analysis identified diabetes mellitus, advancing age, higher BMI, and longer symptom duration as independent predictors of neuropathy. Importantly, the combined multivariate predictive model showed excellent diagnostic accuracy, significantly outperforming individual electrophysiological parameters. These findings emphasize the importance of integrating clinical assessment with detailed nerve conduction studies for early detection and risk stratification. Timely identification of peripheral nerve dysfunction in elderly individuals may facilitate targeted intervention, optimize metabolic control, and reduce disability, falls, and loss of functional independence in the aging population.

Declarations

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