

Distribution and Determinants of Peripheral Neuropathy Among Patients With Type 2 Diabetes Mellitus and Its Association With Insulin Resistance: A Cross-Sectional Study Using Nerve Conduction Studies and Shear-Wave Elastography

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Abstract

Background: Diabetic peripheral neuropathy (DPN) is a common complication of type 2 diabetes mellitus (T2DM). Although chronic hyperglycemia is traditionally considered a major contributor, increasing evidence suggests that insulin resistance and metabolic dysfunction may also play an important role. This study evaluated the distribution of peripheral neuropathy among patients with T2DM and examined its association with insulin resistance assessed using the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), along with structural nerve changes assessed by shear-wave elastography (SWE).

Methods: A hospital-based cross-sectional analytical study was conducted from May 2024 to October 2025 among 100 adults aged 18–65 years with T2DM. Participants underwent clinical assessment, biochemical evaluation, nerve conduction studies (NCS), and SWE of peripheral nerves. Fasting glucose and fasting insulin were used to calculate HOMA-IR. NCS was used to classify participants according to the presence or absence of electrophysiological neuropathy. SWE was performed on the posterior tibial and median nerves. Statistical analysis included comparative tests, correlation analysis, and multivariable logistic regression.

Results: The mean age of participants was 50.1 ± 8.6 years, and 51% were male. The mean duration of diabetes was 8.9 ± 4.4 years. The mean HOMA-IR was 6.0 ± 2.1 . Abnormal NCS findings were observed in 83% of participants. Participants with abnormal NCS had significantly higher HOMA-IR than those with normal NCS (6.10 ± 2.13 vs. 3.03 ± 0.85 , $p < 0.001$). Median nerve stiffness was also significantly higher among participants with abnormal NCS (101.20 ± 21.47 vs. 51.64 ± 12.30 kPa, $p < 0.001$). HOMA-IR showed a strong inverse correlation with motor nerve conduction velocity ($r = -0.78$, $p < 0.001$) and a positive correlation with median nerve stiffness ($r = 0.68$, $p < 0.001$). Median nerve stiffness was strongly inversely correlated with motor conduction velocity ($r = -0.85$, $p < 0.001$). In multivariable logistic regression, HOMA-IR remained significantly associated with abnormal NCS (OR 5.53, 95% CI 1.51–20.46; $p = 0.010$), whereas median nerve stiffness, diabetes duration, and HbA1c were not independently significant.

Conclusion: Peripheral neuropathy was frequent among the studied patients with T2DM. Higher insulin resistance was strongly associated with electrophysiological evidence of neuropathy and structural nerve abnormalities. These findings suggest that insulin resistance may represent an important metabolic factor associated with diabetic peripheral nerve dysfunction. Longitudinal studies are required to establish temporal and causal relationships.

Keywords: Type 2 diabetes mellitus; diabetic peripheral neuropathy; insulin resistance; HOMA-IR; nerve conduction study; shear-wave elastography; median nerve; motor conduction velocity.

1. Introduction

Type 2 diabetes mellitus is a major metabolic disorder associated with multiple microvascular and macrovascular complications. Among these, diabetic peripheral neuropathy is one of the most frequent neurological complications and can substantially affect quality of life and functional status.

Diabetic peripheral neuropathy is characterized by abnormalities involving peripheral sensory, motor, and autonomic nerves. The clinical manifestations may range from asymptomatic electrophysiological abnormalities to pain, paresthesia, sensory loss, weakness, gait impairment, and increased risk of foot ulceration.

Chronic hyperglycemia has traditionally been considered a major pathogenic factor in diabetic neuropathy. However, the metabolic abnormalities accompanying T2DM are complex and include insulin resistance, obesity, oxidative stress, endothelial dysfunction, mitochondrial abnormalities, activation of the polyol pathway, advanced glycation end-product formation, and inflammatory mechanisms.

Insulin resistance is a central feature of T2DM and metabolic syndrome. Its possible contribution to peripheral nerve dysfunction has attracted increasing interest. Assessment of insulin resistance using HOMA-IR provides a relatively simple estimate based on fasting glucose and fasting insulin concentrations.

Nerve conduction studies remain an important objective method for evaluating peripheral nerve function. However, conventional electrophysiological testing primarily evaluates functional abnormalities. Shear-wave elastography provides an additional method for assessing mechanical properties of peripheral nerves by measuring tissue stiffness and may provide information regarding structural alterations.

The present study therefore evaluated the distribution of peripheral neuropathy among patients with T2DM and investigated the relationship between insulin resistance, electrophysiological nerve abnormalities, and nerve stiffness measured using SWE.

2. Materials and Methods

2.1 Study design and setting

This was a hospital-based cross-sectional analytical study conducted between May 2024 and October 2025.

2.2 Study population

The study included 100 adults with type 2 diabetes mellitus, aged 18–65 years. Participants had a duration of diabetes of at least one year and were recruited using purposive/consecutive sampling according to the study protocol.

2.3 Clinical assessment

Participants underwent detailed clinical assessment including demographic characteristics, duration of diabetes, body mass index, blood pressure, and clinical assessment for neuropathic symptoms.

2.4 Biochemical assessment

The biochemical evaluation included fasting blood glucose, postprandial blood glucose, HbA1c, fasting insulin, and HOMA-IR. HOMA-IR was calculated using fasting glucose and fasting insulin values according to the study protocol.

2.5 Nerve conduction studies

Nerve conduction studies were performed in the Neurology department. NCS parameters included nerve conduction velocity, latency, and amplitude. Participants were classified as having abnormal NCS when one or more assessed parameters were outside the laboratory reference range.

2.6 Shear-wave elastography

SWE was performed to assess the mechanical stiffness of peripheral nerves. The median and posterior tibial nerves were evaluated, with multiple measurements obtained and mean stiffness/velocity recorded. Care was taken to minimize excessive transducer pressure during examination.

2.7 Statistical analysis

Data were analyzed using SPSS. Continuous variables were expressed using appropriate measures of central tendency and dispersion, while categorical variables were expressed as frequencies and percentages. Comparative analyses, correlation analyses, and multivariable logistic regression were performed. A p-value ≤ 0.05 was considered statistically significant.

3. Results

A total of 100 participants with T2DM were included. The mean age was 50.1 ± 8.6 years. Males constituted 51% of the study population and females 49%. The mean duration of diabetes was 8.9 ± 4.4 years.

The mean BMI was 29.0 ± 3.4 kg/m², while 70% of participants were hypertensive.

Parameter	Mean $\pm$ SD
Fasting blood glucose	165 ± 24 mg/dL
Postprandial blood glucose	229 ± 39 mg/dL
HbA1c	$9.0 \pm 1.2\%$
Fasting insulin	15.8 ± 5.0
HOMA-IR	6.0 ± 2.1

3.1 Prevalence of electrophysiological neuropathy

Abnormal NCS findings were observed in 83% of participants, while 17% had normal NCS findings.

3.2 Association with diabetes duration, age and gender

Diabetes duration demonstrated a significant association with abnormal NCS findings ($p=0.02$). In contrast, age and gender were not significantly associated with abnormal NCS findings, with p-values of 0.725 and 0.68, respectively.

3.3 HOMA-IR and nerve conduction

Participants with abnormal NCS had substantially higher HOMA-IR values than those with normal NCS (6.10 ± 2.13 vs. 3.03 ± 0.85 , $p < 0.001$). Motor nerve conduction velocity was significantly lower among participants with abnormal NCS (38.48 ± 5.50 vs. 50.43 ± 5.20 m/s, $p < 0.001$).

3.4 Shear-wave elastography

Median nerve stiffness was substantially higher in participants with abnormal NCS (101.20 ± 21.47 vs. 51.64 ± 12.30 kPa, $p < 0.001$).

3.5 Correlation analysis

HOMA-IR demonstrated a strong negative correlation with motor conduction velocity ($r = -0.78$, $p < 0.001$), and a positive correlation with median nerve stiffness ($r = 0.68$, $p < 0.001$). Median nerve stiffness showed a strong inverse correlation with motor conduction velocity ($r = -0.85$, $p < 0.001$).

3.6 Multivariable logistic regression

Variable	OR	95% CI	p-value
HOMA-IR	5.53	1.51–20.46	0.010
Median nerve stiffness	1.03	0.98–1.07	0.261
Diabetes duration	0.88	0.71–1.09	0.248
HbA1c	0.72	0.36–1.44	0.36

4. Discussion

The present study found a high frequency of electrophysiological peripheral neuropathy among the studied patients with T2DM, with abnormal NCS findings observed in 83% of participants.

A major finding was the strong association between insulin resistance and peripheral nerve dysfunction. Participants with abnormal NCS had significantly higher HOMA-IR values than those with normal NCS. Furthermore, HOMA-IR showed a strong inverse relationship with motor nerve conduction velocity.

These findings support the possibility that metabolic dysfunction beyond hyperglycemia may contribute to peripheral nerve abnormalities in T2DM.

The study also demonstrated substantially increased median nerve stiffness among participants with abnormal NCS. The strong inverse correlation between nerve stiffness and motor conduction velocity suggests that structural changes assessed by SWE are closely related to functional electrophysiological abnormalities.

However, the multivariable analysis requires careful interpretation. Although median nerve stiffness was strongly associated with abnormal NCS in unadjusted analysis, it did not remain statistically significant after adjustment for HOMA-IR and other variables. In contrast, HOMA-IR retained a significant association.

The study therefore suggests a relationship between insulin resistance, structural nerve alterations, and functional nerve impairment. However, because this investigation was cross-sectional, these relationships should be interpreted as associations rather than proof of causality. Longitudinal studies are required to establish temporal relationships.

5. Conclusion

Peripheral neuropathy was frequent among patients with T2DM in this study. Higher insulin resistance, measured using HOMA-IR, was strongly associated with abnormal nerve conduction findings and with increased median nerve stiffness. The findings indicate that insulin resistance may be an important metabolic factor associated with diabetic peripheral nerve dysfunction. SWE demonstrated a relationship between nerve structural characteristics and electrophysiological function.

However, the cross-sectional nature of the study prevents causal conclusions. Larger prospective studies with appropriate control groups and standardized SWE protocols are required to determine whether changes in insulin resistance precede and contribute to the development or progression of diabetic peripheral neuropathy.

6. Limitations

- Cross-sectional design, which precludes causal inference.
- Hospital-based sample, which may limit generalizability and may influence the observed prevalence.
- Single time-point measurements of HbA1c and HOMA-IR.
- SWE is operator-dependent and universally accepted reference cut-offs are not established.
- Potential residual confounding from factors such as lipid profile, medications and lifestyle factors.
- Small subgroup sizes may limit the precision of subgroup comparisons.

- No non-diabetic control group was included.

7. Recommendations

- Early neuropathy screening should be considered in patients with T2DM who have metabolic risk factors.
- Assessment of insulin resistance may provide additional metabolic information in patients at risk of peripheral neuropathy.
- Lifestyle interventions addressing obesity and insulin resistance may be considered as part of comprehensive diabetes management.
- Longitudinal studies are required to investigate the temporal relationship between insulin resistance and peripheral nerve dysfunction.
- Standardized SWE acquisition protocols and clinically validated cut-offs should be developed.
- Larger multicenter studies including appropriate non-diabetic control groups are needed.
- Future studies should evaluate whether interventions that improve insulin resistance alter the development or progression of peripheral neuropathy.

8. References

The reference list should be transferred directly from the submitted thesis and formatted according to the target journal's required citation style. This manuscript draft intentionally does not invent or substitute references that were not verified from the source document.

9. Declarations

Ethics approval

To be completed from the ethics approval details stated in the original thesis.

Consent to participate

To be completed from the original thesis protocol.

Funding

Not stated in this manuscript draft; verify against the original thesis.

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Data availability

To be completed according to institutional and journal requirements.