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Original Research Article

Silent Feet: Unveiling the Burden of Diabetic Peripheral Neuropathy in Rural Communities

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Abstract: ***Background:***Diabetic Peripheral Neuropathy (DPN) is a common and disabling microvascular complication of Type 2 Diabetes Mellitus (T2DM), often leading to pain, foot ulcers, infections, and amputations. Early detection is critical, yet in rural India many cases remain undiagnosed until advanced stages. This study assessed vibration perception threshold (VPT) using a biothesiometer and examined the association between diabetes duration and neuropathy severity. ***Methods:*** A community-based cross-sectional study was conducted among 270 adults with T2DM in rural field practice areas of Chengalpattu district. Peripheral neuropathy was evaluated using a biothesiometer. Data were analysed with IBM-SPSS v27. Qualitative variables were expressed as proportions and quantitative variables as mean (SD) or median (IQR). Chi-square tests and regression analyses explored associations. ***Results:*** Among participants, numbness (52.2%) and burning or aching pain (35.2%) were the most common symptoms. Diabetes duration >7 years, smoking, and alcohol use significantly increased the odds of reduced vibration sensation (OR ≈ 2.0). In multivariable analysis, female gender was protective against DPN (OR: 0.194, 95% CI: 0.082–0.455), while certain occupations showed higher risk (OR: 1.24, 95% CI: 1.061–1.449). After adjustment, age, diabetes duration, BMI, and medication type were not independent predictors. ***Conclusion:*** Peripheral neuropathy prevalence was high (51.1%) in this rural cohort. Female gender and occupation emerged as stronger predictors than traditional factors. Routine biothesiometer-based screening can support earlier detection in resource-limited primary care settings.

Keywords: T2DM, Diabetic Peripheral Neuropathy, Biothesiometer, VPT

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INTRODUCTION

According to WHO, about 422 million people worldwide have diabetes, the majority living in low- and middle-income countries, and 1.5 million deaths are directly attributed to diabetes each year(1). The nations progress towards 2030 agenda for Sustainable development goal (SDG) which has a specific target 3.4 to "reduce by one third premature mortality from non-communicable disease through prevention and treatment and promote mental health and wellbeing(2). According to National Family Health Survey-5 (NFHS-5) prevalence of Type 2 Diabetes Mellitus is 19.3%(3).

Diabetic neuropathy (DN) is one of the main microvascular complications of both type 1 and type 2 diabetes mellitus. Sometimes, this could already be present at the time of diagnosis for type 2 diabetes mellitus (T2DM), while it appears in subjects with type 1 diabetes mellitus (T1DM) almost 10 years after the onset of the disease. Manifestations of diabetic neuropathy (DN) vary and depend on the nervous system involved (peripheral sensory/motor or vegetative), thus determining a complex picture of symptoms and signs depending on the organ involved. However, peripheral neuropathy is the most common and, as well described by recent guidelines, could affect almost 50% of individuals with diabetes mellitus (DM) during their lifetime(4).
The most common clinical symptoms of DPN are symmetrical limb pain, a tingling sensation, and numbness, particularly at the distal end (i.e., DSPN) in the so-called glove and stocking pattern. Approximately half of those with DPN experience worsening symptoms at night, when tired, or when stressed. In the advanced stages of DPN, weakness, poor balance, and unsteadiness can manifest(5). Early detection of DPN and implementation of appropriate preventive measures are important elements in the management of individuals with diabetes. International guidelines from various professional associations have recommended periodic screening, at least annually, for DPN(6).
The prevalence of Diabetic Peripheral Neuropathy using Biothesiometer, 98.1% (95% CI: 93.3-99.5) which was higher than the other two screening methods (monofilament and MNSI examination)(7).

Rationale:
Diabetic Peripheral Neuropathy (DPN) is a common and debilitating complication of diabetes mellitus, often leading to chronic pain, ulcers, infections, and amputations. Despite the rising burden of diabetes, rural populations face challenges such as limited healthcare access and low awareness, resulting in delayed detection and advanced neuropathy at presentation. This study addresses the knowledge gap on DPN in rural areas by identifying its prevalence, risk factors, and barriers to care to guide targeted interventions that improve outcomes and quality of life.

Objective:
• To measure and evaluate the vibration perception threshold (VPT) in individuals with diabetes using a biothesiometer.
• To identify the correlation between the duration of diabetes and the severity of peripheral neuropathy as assessed by VPT.

MATERIALS AND METHODS

The study was a community-based Cross Sectional Study conducted in the rural area of Chengalpattu district, field practice area of a tertiary care hospital. Duration of the study was 6 months. Study population was known case of Type 2 Diabetes Mellitus residing in the study area permanently at the time of the study. The study included individuals aged above 18 years who were known cases of diabetes mellitus for at least one year. Patients with foot amputations, those already receiving treatment for peripheral neuropathy, and individuals with kidney disease, liver disease, a history of

chemotherapy, or chronic alcoholism were excluded from the study. Sample size with reference to National Family Health Survey-5 (2019-21) prevalence of type 2 Diabetes is 19.3%. Considering it as a prevalence with 95% confidence interval, the allowable error of 5%, the sample size is 240. To account for a non-response rate 10%, 270 will be the sample size for this study.

This cross-sectional study has been conducted in outreach health centres located in rural field practice areas of an affiliated with a tertiary care institute. Out of the 8 rural outreach health centres, 4 was randomly selected. Type 2 Diabetic patients visiting these selected clinics during the study period of six months (March 2025 to August 2025) was included.

Questionnaire that contains 5 sections

1. Part A: Socio demographic details
2. Part B: Diabetic history
3. Part C: General examination
4. Part D: Foot examination
5. Part E: Diabetic neuropathy symptom score (DNS)

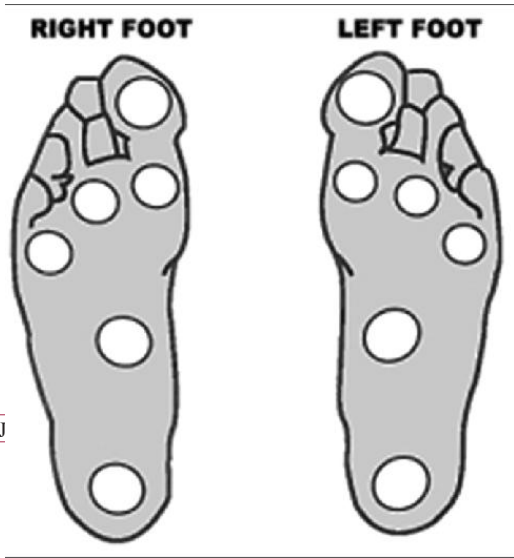
Data collection:

1. After obtaining consent from patients with Type 2 Diabetes information regarding demographics, socioeconomic and lifestyle characteristics has been collected by interviewing the participant.
2. Bio-thesiometer was used to assess the degree of Peripheral neuropathy

Assessment of Peripheral Neuropathy using Biothesiometer

Biothesiometer is an instrument that can detect and quantify diabetic peripheral neuropathy in its early stages. It functions similarly to an electronic tuning fork. The biothesiometer was used to assess vibration perception threshold (VPT) in study participants. The test was conducted in a quiet room with the participant seated comfortably. Feet were cleaned and dried before assessment.

The procedure was explained before testing. The probe of the biothesiometer was placed gently on six standard sites of one foot: Great toe (hallux), first metatarsal head, third metatarsal head, fifth metatarsal head, instep (medial arch) and heel. At each site, the voltage was gradually increased, and the participant was asked to indicate as soon as vibration was first perceived. The voltage reading at that point was noted as the vibration perception threshold. Each site was tested twice, and the mean value was calculated. The overall VPT for the foot was derived by averaging the six site readings. For interpretation, a VPT value of ≤15 volts was considered normal, 16–25 volts indicated mild neuropathy, 26–40 volts indicated moderate neuropathy, and >40 volts was taken as severe neuropathy.



Data entry and analysis:
The collected data has been analysed using IBM-SPSS software version 27.0. The qualitative variables will be expressed in proportions and quantitative variables in mean (SD)/ median (IQR). All the necessary statistical tests will be applied. Statical tests to be applied are Chi-square for qualitative variable and regression will be done to analyse the association between qualitative variables.

Ethical consideration:
The study proposal has been approved by institutional human ethics committee (Ref No: IHEC-I/3659/25)

RESULTS

Table 1- The study sample (N=270) had a mean age range of 31–40 years (57%). Female participants slightly outnumbered males (51.9% vs. 47.4%). Most participants were educated up to intermediate/diploma (18.1%), professional (17.8%), or unskilled workers (17%). A majority were financially independent (37%), with 51.1% having diabetes for >7 years. Family history of DM was present in 59.6%, and most were on oral hypoglycemic agents (79.6%).

Table 4 This logistic regression analysis evaluated a range of sociodemographic, clinical, and symptom variables to identify independent predictors of diabetic peripheral neuropathy (DPN). Odds ratio (OR) for age was 1.017 (95% CI: 0.978–1.057, p = 0.394), indicating that age by itself was not a statistically significant predictor of DPN. Female gender was associated with significantly lower odds of DPN compared to males (OR: 0.194, 95% CI: 0.082–0.455, p < 0.001), suggesting a protective effect for women in this sample. Both education (OR: 1.1, 95% CI: 0.94–1.286, p = 0.236) and financial status (OR: 1.126, 95% CI: 0.772–1.643, p = 0.536) did not show a statistically significant association with neuropathy outcomes. The occupation variable was significantly linked to DPN (OR: 1.24, 95% CI: 1.061–1.449, p = 0.007), indicating certain job categories may confer a higher risk. No significant association was found between BMI and DPN (OR: 1.027, 95% CI: 0.599–1.761, p = 0.923). While the odds of neuropathy were higher in patients with diabetes >7 years (OR: 1.182, 95% CI: 0.909–1.539), this association did not reach statistical significance (p = 0.213). The type of medication (Insulin or OHA) showed no significant effect on DPN risk (OR: 1.344, 95% CI: 0.695–2.6, p = 0.38). Individual symptoms such as unsteadiness, numbness, pain, or prickling (DNS score composite OR: 0.911, 95% CI: 0.381–2.178, p = 0.834) were not significant independent predictors.

Only gender and occupation showed statistically significant associations with diabetic peripheral neuropathy, while other classical risk factors such as age, BMI, education, financial status, diabetes duration, medication type, and neuropathy symptoms were not independently predictive when adjusting for covariates. This highlights the importance of contextual factors in rural and community settings and suggests that gender and certain occupational exposures may play a stronger role in DPN risk than previously

Table 1. Demographic details of study participants (n=270)

Socio demographic profile	n (%)
Age (in years)	

18-20	45(16.7)
21-30	70(25.9)
31-40	154(57)
41-50	45(16.7)
51-60	70(25.9)
Gender	
Male	128(47.4)
Female	140(51.9)
Educational qualification	
Graduate	36(13.3)
High school	28(10.4)
Illiterate	33(12.2)
Intermediate/diploma	49(18.1)
Middle school	35(13.0)
Primary school	47(17.4)
Professional Degree	42(15.6)
Occupation	
Clerical/ shop/ farm worker	31(11.50)
Professional	48(17.80)
Semi-professional	27(10.00)
Semi-skilled worker	44(16.30)
Skilled worker	40(14.80)
Unskilled worker	46(17.00)
Unemployed	34(12.60)
Financial status	
Fully dependent	85(31.50)
Independent	100(37.00)
Partially dependent	85(31.50)
Duration of Type 2 Diabetes Mellitus (in years)	
>7	138(51.1)
≤7	132(48.9)
Family history of DM	
Yes	161(59.6)
No	109(40.4)
Type of Diabetic Medication	
Insulin	31(11.5)
Oral hypoglycemic agents	215(79.6)
Insulin and Oral hypoglycemic agents	24(8.9)

Table 2- In this study, just under one-third of participants (84, 31.1%) said they felt unsteady while walking, while about 69% did not. Numbness was experienced by slightly over half the group (141, 52.2%), making it the most common symptom. More than a third (95, 35.2%) reported burning, aching pain, or tenderness in their legs or feet, and a similar proportion (90, 33.3%) described prickling sensations. Overall, numbness stood out as the leading symptom among those surveyed, followed by pain and tingling sensations, while unsteadiness affected a significant minority.

Table 3 shows analysis of risk factors associated with the loss of vibration sensation, assessed by biothesiometer, among T2DM patients. Patients with diabetes >7 years have more than double the odds (OR 2.21, 95% CI 1.23–3.99) of vibration sensation loss compared to those ≤7 years. No statistically significant difference was observed between insulin and oral hypoglycemic agents in risk for vibration loss (OR 0.776, CI 0.421–1.428). No statistically significant difference was observed between insulin and oral hypoglycemic agents in risk for vibration loss (OR 0.776, CI 0.421–1.428). No statistically significant difference was observed between insulin and oral hypoglycemic agents in risk for vibration loss (OR 0.776, CI 0.421–1.428). Absence of ankle jerk had a non-significant marginally increased risk for vibration loss (OR 1.11, CI 0.62–1.97). Both smoking and alcohol history nearly doubled neuropathy risk (OR 1.99, CIs ~1.08–3.70) and were significant

Table 2 Diabetic neuropathy symptom score (DNS) (n=270)

Diabetic neuropathy symptom score (DNS)	Frequency (%)
1. Unsteadiness in walking a) Absent b) Present	 186(68.9) 84(31.1)
2. Numbness a) Absent b) Present	 129(47.8) 141(52.2)
3. Burning, aching pain or tenderness in legs or feet a) Absent b) Present	 175(64.8) 95(35.2)
4. Prickling sensations a) Absent b) Present	 180(66.7) 90(33.3)

Table 3 Vibration perception threshold (VPT) among T2DM patients using a biothesiometer (n=270)

	Vibration sensation (n=270)		OR (95%CI)
	Present	Lost	
Duration of Diabetes			
≤7 years	39	93	2.211(1.23 – 3.99)
>7 years	22	116	
Medication			
Insulin	42	77	0.776 (.421-1.428)
Oral hypoglycemic agents (OHA)	19	132	
DNS score			
0	9	37	
≥1	52	172	1.243(.563-2.743)
Calf circumference (in cms)			
<35	18	64	1.054(.565-1968)
>35	43	145	
Ankle jerk			
Present	35	125	1.105(.620-1.970)
Absent	26	84	
History of smoking			
Yes	39	163	1.999(1.079-3.703)
No	22	46	
History of alcohol			
Yes	39	163	1.999(1.079-3.703)
No	22	46	

Table 4 Multivariable Logistic Regression Analysis of diabetic peripheral neuropathy and related variables

Variables	OR	95% CI	P-value
Age	1.017	0.978 - 1.057	0.394
18-20	-		
21-30	-		
31-40	-		
41-50	-		
51-60	-		
Gender			
Male	-		
Female	0.194	0.082 – 0.455	0
Education			
Graduate	1.1	0.94 – 1.286	0.236
High school	-		
Illiterate	-		
Intermediate/diploma	-		

Middle school Primary school Professional Degree	- - - -		
Occupation Clerical/ shop/ farm worker Professional Semi-professional Semi-skilled worker Skilled worker Unskilled worker Unemployed	1.24 - - - - - -	1.061 – 1.449	0.007
Financial status Fully dependent Independent Partially dependent	1.126 - -	0.772 – 1.643	0.536
BMI	1.027	0.599 - 1.761	0.923
Duration_of_diabetes ≤7 years >7 years	1.182 -	0.909 - 1.539	0.213
Medication Insulin Oral hypoglycemic agents Insulin and Oral hypoglycemic agents	1.344 - -	0.695 – 2.6	0.38
DNS_score Unsteadiness in walking Numbness Burning, aching pain or tenderness in legs or feet Prickling sensations	0.911 - - -	0.381 - 2.178	0.834

DISCUSSION

Primary objective of the study was to identify the correlation between the duration of diabetes and the severity of peripheral neuropathy as assessed by VPT. In this study findings indicate a significant burden of DPN in this community, highlighting the critical need for early and accessible screening methods. Univariate analysis revealed that a longer duration of diabetes, smoking, and alcohol use were significantly associated with DPN. However, in the multivariable logistic regression analysis, only female gender and occupation remained as statistically significant independent predictors.

The prevalence of DPN in our study (51.1%) is considerably high and underscores the scale of this complication in rural settings. This figure is strikingly similar to the 51.1% prevalence found by Perveen et al. (8) in Pakistan through clinical foot examination and is comparable to the 44.9% reported by Jasmine et al. (9) in another rural South Indian cohort. In contrast, our prevalence is substantially higher than the 28.85% reported in New Delhi by Baxi et al. (2) and the 38% found in an urban Gujarati population by Solanki et al. (10). The lower rate in the latter study may be partly explained by their use of a higher, more conservative VPT cutoff (>25V) for diagnosis. Conversely, our finding is lower than the 67.6% prevalence documented in a large-scale Chinese study by Wang et al. (11). These wide variations in prevalence rates are likely attributable to differences in diagnostic methodologies, VPT thresholds, population demographics, and regional or environmental factors. Nonetheless, our results align with the global trends described by Khan et al. (12), Raja et al. (13)and Saeedi et al. (14), which indicate a rising burden of diabetes and its complications, particularly in low- and middle-income countries.

Our study identified a strong univariate association between a longer duration of diabetes (>7 years) and DPN, a finding consistent with robust evidence from several studies (15) (11) . However, this association did not maintain statistical significance in our multivariable model, suggesting that in our specific rural cohort, other factors may have a more powerful independent influence. This aligns partially with Solanki et al. (10), who also found that other predictors could outweigh duration. Similarly, while advancing age is a well-established risk factor for DPN (16) (11) (17), it was not a significant predictor

in our final model, a finding that mirrors the results of Solanki et al. (10).

Poor glycemic control has been identified as a primary modifiable risk factor for DPN in numerous studies. Baxi et al. (15), Jasmine et al. (18), and Patel et al. (16) all demonstrated a significant, independent association between elevated HbA1c levels and the presence of neuropathy. The lack of this data in our analysis prevents a more comprehensive risk assessment and may have influenced the observed significance of other variables.

The most notable findings from our multivariable analysis were the independent roles of gender and occupation. The significant protective effect observed for the female gender stands in sharp contrast to much of the literature; it directly opposes findings from Wang et al. (11)of a higher DPN prevalence in females, while other studies found either a higher risk in males (10) or no significant gender association at all (16,19). This disparity suggests the influence of unmeasured gender-specific variables in our population, such as differences in occupational physical activity, lifestyle, or healthcare-seeking behaviors.

Regarding lifestyle factors and comorbidities, our study found a significant univariate association between DPN and both smoking and alcohol use. The link with smoking, however, contrasts with the findings of Patel et al. (16), who did not find a significant association. This difference may be due to regional variations in smoking habits or other lifestyle patterns. Our study did not find associations with other common comorbidities, and data on factors like hypertension and dyslipidemia were not collected, which were identified as significant predictors in other populations (11).

In this study, the type of diabetic medication (insulin vs. oral agents) was not significantly associated with DPN. This aligns with the findings of Patel et al. (16), who also reported no association with the method of diabetes control. While we did not assess medication adherence, its importance is highlighted by Samu et al. (20), who demonstrated that improving adherence significantly reduced DPN severity, suggesting this is a crucial area for clinical intervention and future research. In another study done Arunagiri et al. (21)showed poor glycemic control showed a positive association with DPN.

Strength:
The use of a biothesiometer was central to our methodology. Its value as a reliable, quantitative screening tool is well-supported by studies demonstrating its strong correlation with and high sensitivity compared to nerve conduction studies (19,22). Our application of this tool to identify individuals at risk aligns with the conclusions of Annadurai et al. (23), who highlighted its utility in revealing the DPN burden in another rural Tamil Nadu demography.

Limitations:
Cross-sectional design precludes causal inference, its single-center nature limits generalizability, potential selection bias from recruiting at health centers and most importantly, the lack of glycemic control data.

CONCLUSION

In conclusion, this study confirms a high prevalence of peripheral neuropathy among diabetic patients in a rural community. Uniquely, occupation and a protective female gender effect emerged as stronger independent predictors than traditional risk factors. These findings underscore the critical value of the biothesiometer for early DPN detection in low-resource settings. We recommend integrating routine biothesiometer screening into primary diabetes care and developing targeted educational programs focused on occupational risks. Future research should prioritize prospective, multi-center studies that include glycemic and adherence data to validate these findings and explore the specific mechanisms behind occupational and gender-related risks.

Operational definition:
1. Diabetes- Chronic disease that occurs either when the pancreas does not produce enough insulin or when the body cannot effectively use the insulin it produces. Insulin is a hormone that regulates blood glucose. Hyperglycaemia, also called raised blood glucose or raised blood sugar, is a common effect of uncontrolled diabetes and over time leads to serious damage to many of the body's systems, especially the nerves and blood vessels(24).
2. Type 2 Diabetes- A participant will be considered as having Type 2 Diabetes Mellitus if they are a known case of T2DM diagnosed by a registered medical practitioner and on treatment (oral hypoglycemic agents and/or insulin) for at least one year prior to the study period. Diagnosis must have been based on standard criteria such as fasting plasma glucose ≥126 mg/dl (7.0 mmol/L), 2-hour plasma glucose ≥200 mg/dl (11.1 mmol/L) during an oral glucose tolerance test, HbA1c ≥6.5%, or random plasma glucose ≥200 mg/dl (11.1 mmol/L) with symptoms of hyperglycemia, as per ADA/WHO guidelines.
3. Diabetic Peripheral Neuropathy (DPN)- Defined as the presence of impaired vibration perception as measured using a biothesiometer. The Vibration Perception Threshold (VPT) was recorded in 6 sites on both feet. A VPT value of >15 volts was considered indicative of peripheral neuropathy. Severity was graded as:
Mild neuropathy: 16–25 volts

Moderate neuropathy: 26–40 volts
Severe neuropathy: >40 volts

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