Nurse Media JOURNAL OF NURSING

Nurse Media Journal of Nursing
e-ISSN: 2406-8799, p-ISSN: 2087-7811
https://medianers.undip.ac.id
15(2):239-252, August 2025
https://doi.org/10.14710/nmjn.v15i2.56936

ORIGINAL RESEARCH

The Risk of Diabetic Peripheral Neuropathies among Diabetic Patients Living in Urban and Rural Areas

Arina Qona'ah[1], Ika Nur Pratiwi[1], Zulfayandi Pawanis[2], Laura Navika Yamani[3], Eskarani Tri Pratiwi[4], Nursalam Nursalam[5], Vimala Ramoo[6]

[1]*Medical-Surgical, Emergency, Critical and Disaster Nursing Department, Faculty of Nursing, Universitas Airlangga, Surabaya, Indonesia*
[2]*Airlangga University Hospital, Universitas Airlangga, Surabaya, Indonesia*
[3]*Department of Epidemiology, Faculty of Public Health, Universitas Airlangga, Surabaya, Indonesia*
[4]*Faculty of Medicine and Health Science, Universitas Mataram, Mataram, Indonesia*
[5]*Management, Fundamental, Mental Health and Community Nursing Department, Faculty of Nursing, Universitas Airlangga, Surabaya, Indonesia*
[6]*Faculty of Medicine, University of Malaya, Kuala Lumpur, Malaysia*

Article Info

Article History:
Received: 31 July 2023
Revised: 21 August 2025
Accepted: 29 August 2025
Online: 31 August 2025

Keywords:
Delivery of health care; diabetic neuropathies; rural population; type 2 diabetes mellitus; urban population

Corresponding Author:
Ika Nur Pratiwi
Medical-Surgical, Emergency, Critical, and Disaster Nursing Department, Faculty of Nursing, Universitas Airlangga, Surabaya, Indonesia
E-mail:
ikanurpratiwi@fkp.unair.ac.id

Abstract

Background: Diabetic Peripheral Neuropathy (DPN) is a common complication of type 2 diabetes mellitus (T2DM), and is closely linked to poor glycemic control. However, little is known about how environmental and lifestyle differences between urban and rural settings affect the risk of DPN.
Purpose: This study aimed to identify and compare the risk factors of DPN among T2DM patients living in rural and urban areas.
Methods: A comparative cross-sectional design with convenience sampling was used to recruit 156 T2DM patients from both urban (Surabaya) and rural (Lamongan) areas of East Java, Indonesia. Data were collected using the Vascular Quality of Life-6 (VQ-6), Diabetic Neuropathy Symptom (DNS), Diabetic Neuropathy Examination (DNE), and Ankle-Brachial Index (ABI). Logistic regression was performed for analysis, with a significance level set at $p<0.05$.
Results: The mean age of rural participants was 55.86 (SD=8.4) years, slightly younger than that of urban participants at 57.27 (SD=9.3) years. Urban residents had higher education levels (37.7%), but engaged less in regular physical activity (51.9%). The risks of DPN were significantly higher in rural areas ($p<0.05$), with key contributing factors including higher ABI (OR=17.07), more diabetic neuropathic symptoms (OR=3.35), multiple diabetes medications (OR=10.27), lower physical activity (OR=0.24), and lower education level (OR=0.25). Of these, ABI was the strongest predictor of DPN risks.
Conclusion: Rural T2DM patients are at greater risk of DPN due to vascular and neuropathic complications combined with sociodemographic disadvantages. These findings highlight the importance of early detection and tailored education programs for rural communities to prevent and manage DPN.

How to cite: Qona'ah, A., Pratiwi, I. N., Pawanis, Z., Yamani, L. N., Pratiwi, E.T., Nursalam, N., Ramoo, V. (2025). The risk of diabetic peripheral neuropathies among diabetic patients living in urban and rural areas. *Nurse Media Journal of Nursing, 15*(2), 239-252. https://doi.org/10.14710/nmjn.v15i2.56936

1. Introduction

Diabetes mellitus (DM) is a critical public health problem. A total of 588.7 million people had diabetes worldwide in 2024, and it is estimated that the number will increase by 45% in 2050. The incidence is higher in low- and middle-income countries, with 3 in every 4 adults having DM (International Diabetes Federation, 2025). Urban areas had a higher diabetes prevalence (12.1%) than rural areas (8.3%) (Sun et al., 2022). Indonesia, a middle-income country, is the fifth highest country with diabetes cases in the world, with 28.6 million living with DM, and projections estimated that the national diabetes prevalence will rise from 9.19% in 2020 (18.7 million cases) to 16.09% in 2045 (40.7 million cases) (Wahidin et al., 2024). The province of East Java had the 5th-highest prevalence of DM in Indonesia in 2018, and type 2 DM accounted for 57% of all DM cases in East Java hospitals (Ministry of Health, Republic of Indonesia, 2018). It is estimated that

80% of the global population with diabetes lives in developing countries, including Indonesia (Katulanda et al., 2012).

Recent studies show that disparities in healthcare access, lifestyle behaviors, socioeconomic conditions, and health literacy contribute to differences in the risks and management of diabetic peripheral neuropathy (DPN) between rural and urban areas. Rural residents, whose livelihoods are predominantly related to agriculture or manual labor, often face higher barriers to preventive care, limited healthcare facilities, and lower awareness of neuropathic symptoms, leading to delayed diagnosis and treatment of DPN (Sun et al., 2022). Meanwhile, urban dwellers, many of whom are engaged in office-based occupations, generally have better access to healthcare but are more likely to adopt sedentary lifestyles and unhealthy diets, which increase metabolic risk factors (Tripathy et al., 2017). Therefore, understanding these contextual differences is crucial for designing targeted interventions and early detection programs for DPN in Indonesia.

Diabetic peripheral neuropathy (DPN) significantly decreases patients' quality of life and imposes a considerable burden on healthcare systems (Sun et al., 2025). DPN was operationally defined as the presence of neuropathic symptoms and signs in the lower extremities, including neurological deficits, sensory complaints, and vascular complications. These symptoms could be assessed using the Diabetic Neuropathy Symptom (DNS-Ina) and Examination (DNE) scores, the Ankle-Brachial Index (ABI), and the VascuQoL-6 questionnaire. This combined approach allowed a comprehensive evaluation of both neuropathic and vascular components associated with DPN (Elafros et al., 2022). DPN is one of the complications in a patient with type 2 diabetes. The more uncontrolled DM, the faster the neuropathy develops (Amelia et al., 2018). DPN affects 30-50% of people with diabetic foot ulcers (Yang et al., 2018). Patients rarely treat neuropathy because they do not know the symptoms, and this problem interferes with the patient's quality of life. In the United States, 60-70% of T2DM patients develop complications of DPN (Lutfiyya et al., 2011), while in Indonesia, 43% of 16,800 T2DM patients had neuropathy and were at risk for amputations (Rahmawati & Hargono, 2018).

Early identification and prevention can be used to prevent worsening of neuropathy. Early detection of neuropathy is essential in DM patients, and preventive interventions are used to reduce morbidity (Amelia et al., 2018). Most studies on DM's prevalence and risk factors are from developed countries, while data from developing countries are relatively few, especially from the Asian region (Mørkrid et al., 2010). Environmental factors, such as urbanization, lifestyle, and genetic susceptibility, are considered possible causes of the T2DM epidemic in Asia (Lee et al., 2010). The prevalence of undetected micro- and macrovascular complications of DM is higher in rural areas than in urban areas due to poor diabetes control, limited awareness, and limited access to health services (Deepa et al., 2014; Govindarajan Venguidesvarane et al., 2020).

Few studies have been conducted to identify the contemporary prevalence and risk factors of DPN in urban and rural T2DM patients in Indonesia, including the province of East Java. Recent research in Indonesia is generally single-center and cross-sectional, focusing on individual risk factors such as glycemic control, diabetes duration, and dyslipidemia in urban clinic populations (Amelia et al., 2019; Susanti et al., 2025). Meanwhile, national studies have shown substantial heterogeneity and inconsistent diagnostic methods, without considering stratification by residence (Agnez et al., 2025; Contesa et al., 2025; Malik et al., 2020; Susanti et al., 2025). However, it should be noted that environmental factors can affect the development or progression of T2DM differently between urban and rural residents (Aung et al., 2018; Mekuria-Negussie & Tilahun-Bekele, 2024; O'Connor & Wellenius, 2012; Yang et al., 2024). Rural residents often face limited access to healthcare services, including fewer facilities and medical professionals, leading to delayed diagnosis and management of diabetes complications (O'Connor & Wellenius, 2012). They also contend with lower health literacy and socioeconomic constraints, which reduce adherence to self-care and preventive behaviors (Wang et al., 2024). In contrast, urban residents, despite better access to healthcare, are typically exposed to sedentary lifestyles, higher stress levels, and diets rich in processed foods, all of which contribute to poor glycemic control and increased DPN (Ramalivhana et al., 2024; Talukder et al., 2024). Consequently, a study comparing risks of DPN between rural and urban T2DM patients that uses standardized screening and adjusts for clinical and contextual determinants directly fills the current evidence gap.

Although the data collection was conducted more than five years ago, this study remains highly relevant and significant for several reasons. So far, studies in Indonesia have not addressed the risk of diabetic peripheral neuropathy (DPN) in type 2 diabetes patients by comparing urban and rural populations, particularly within the context of East Java. Most existing Indonesian studies have focused only on the prevalence of DPN in single settings or hospital-based populations without comparing geographic or environmental differences (Susanti et al., 2025; Aleidan et al., 2020). DPN continues to be a major complication of diabetes worldwide, and its burden has not decreased over time (Pop-Busui et al., 2017; Tesfaye et al., 2010). In Indonesia, the prevalence of type 2 diabetes is increasing, particularly in rural communities, where access to health care and early detection of complications remain limited (Soewondo et al., 2013). Understanding the factors that influence DPN occurrence in urban and rural areas enables the identification of the best ways to prevent it. Therefore, this study aims to describe the risk of DPN among T2DM patients living in rural and urban areas of East Java Province, Indonesia.

2. Methods

2.1. Research design

A descriptive comparative design with a cross-sectional approach was adopted in this study. This design was used to compare risk factors for DPN between rural and urban areas in T2DM. It is suitable for identifying and comparing characteristics, health outcomes, or risk profiles between two or more groups at a single point in time (Polit & Beck, 2017). The cross-sectional approach is commonly used in epidemiological and clinical studies because it allows researchers to assess the prevalence of a condition and examine associations between variables efficiently, without long-term follow-up (Setia, 2016).

2.2. Setting and samples

Participants who met the following inclusion criteria were included: (1) people who lived in a village or a city for more than six months (this period aligns with definitions used in Indonesia's national health surveys (Riskesdas), which employ a ≥6-month residency threshold to determine usual place of living and to ensure adequate exposure to the area's environmental and health-related factors) (National Institute of Health Research and Development, 2018), (2) people who were diagnosed with DM for two years or more, and (3) people aged 30 years and above. The exclusion criteria were T2DM patients with diabetic foot ulcers. Convenience sampling was used to recruit eligible T2DM patients attending primary health care during the study period, making the process practically feasible within the available time and resource constraints (Elfil & Negida, 2017; Etikan, 2017). The sample size was calculated using the standard formula for comparison of two proportions (two-sided α=0.05, power=80%). The input parameters required for the calculation were the expected proportions in each group, the significance level, the desired power, and the allocation ratio. The estimated sample per group from this calculation was adjusted to account for a 10% non-response rate. This followed standard epidemiologic practices (Daniel & Cross, 2013; Kadam & Bhalerao, 2010; Lwanga & Lemeshow, 1991; Setia, 2016).

The population was selected using similar numbers from both rural and urban areas. A total of 156 participants were calculated from the sample size estimation, divided into 77 patients from the city of Surabaya, representing urban areas, and 79 patients from Lamongan district, a rural area in the province of East Java, Indonesia. Although the numbers were not identical, they were considered equivalent for comparative analyses, as minor differences in final group size commonly occurred due to variations in participant availability and eligibility during community-based data collection. Such small deviations did not meaningfully affect statistical power or group comparability in cross-sectional studies (Leyrat et al., 2024; Makwana et al., 2023; Setia, 2016). Surabaya was chosen to represent the urban area as the capital of East Java, a metropolitan area with a population over 3 million, high population density, better healthcare infrastructure, and mostly engaged in office, service, or industrial work (The Central Bureau of Statistics Surabaya, 2021). Conversely, Lamongan was selected to reflect a rural area, given its agriculture-dominated economy, lower population density, and more restricted access to healthcare services (The Central Bureau of Statistics, Lamongan Regency, 2021). These distinctions provided a strong basis for comparing how environmental and lifestyle differences contributed to the risks of DPN among individuals with T2DM.

2.3. Measurement and data collection

In this study, the risk of diabetic peripheral neuropathy (DPN) was assessed using the Diabetic Neuropathy Symptom Score (DNS-Ina), which had been validated for Indonesian populations as a simple screening tool. Additional examinations included the Diabetic Neuropathy Examination (DNE) for clinical signs, the VascuQoL-6 (VQ-6) for vascular-related quality of life, and the Ankle–Brachial Index (ABI) for vascular function. The researchers conducted measurements of Fasting Capillary Blood Glucose (FCG), Ankle Brachial Index (ABI), and vascular examinations. All procedures were performed by trained health professionals, including nurses and physicians experienced in diabetes care and vascular assessment, ensuring the accuracy and reliability of the data collection. Neurological examinations for DPN were conducted by trained physicians specializing in diabetes care and neurology, supported by trained research nurses. Prior to data collection, all examiners underwent a standardized familiarization and training process, which included: (1) a review of the examination protocol and criteria for each neurological test; (2) a hands-on demonstration session led by a senior neurologist; (3) supervised practice sessions on volunteer subjects to ensure consistency in test administration; and (4) calibration of scoring through inter-observer comparison. Examiners were required to achieve agreement on test procedures and scoring before they were allowed to perform the assessments independently.

Data were collected between August and October 2019 at primary health care centers in Lamongan and Surabaya. The data included demographic and lifestyle characteristics (age, residence, gender, exercise habits, education, smoking habits, history of drug or medication use, and duration of diabetes diagnosis) as well as clinical assessments using the VQ-6, DNS, DNE, and ABI questionnaires. Trained examiners assisted with participant recruitment, appointment coordination, and administration of the demographic and lifestyle questionnaires under the supervision of the research team. Recruitment was conducted at both primary health centers. Oral and written information was provided, and participants who met the inclusion criteria and agreed to take part were asked to sign an informed consent form. Participants were also asked to select preferred data collection times and to fast for at least 8 hours before their appointment.

Researchers collected capillary blood samples from participants using the Easy Touch glucose meter to measure the FCG. The Easy Touch glucose meter was calibrated and quality-checked daily using the manufacturer's control solutions to ensure accurate fasting capillary blood glucose measurements (Dai et al., 2004). The FCG test is an appropriate tool for mass screening to detect diabetes and pre-diabetes with acceptable test properties (Zhao et al., 2013). In this study, classification of participants with type 2 diabetes mellitus was not based solely on FCG results. DM status was also confirmed by a documented history of medical diagnosis by a physician and/or HbA1c test results (≥6.5%), in accordance with the American Diabetes Association (2010) and the national guideline published by the Indonesian Society of Endocrinology (2021). The FCG test in this study was used to reflect participants' current glycemic control status.

ABI examination was carried out by comparing the ratio of leg systolic blood pressure (ankle) and arm (brachial) systolic blood pressure using a Riester Precisa N Aneroid Sphygmomanometer (Miller, 2012). This examination is considered the most superficial screening examination to detect vascular complications, i.e., peripheral arterial disease (PAD); however, it is non-invasive, cost-effective, and suitable for primary care settings (American Diabetes Association, 2023; Noor et al., 2017). The ABI calculation formula is the leg systolic value divided by the arm systolic value. The average value of ≤0.90 was considered abnormal and an indication of PAD or vascular dysfunctions (Aboyans et al., 2018; Curry et al., 2018; Gerhard-Herman et al., 2017). Two measurements were taken on each leg after the participant had rested for at least 10 minutes in a supine position. The average value was used for analysis. Respondents were instructed to avoid smoking, caffeine intake, and vigorous physical activity for at least 30 minutes prior to the examination. Blood pressure cuffs were applied to both arms and ankles, and systolic pressures were obtained using a Riester Precisa N Aneroid Sphygmomanometer. The sphygmomanometer was checked and calibrated according to the manufacturer's guidelines.

The vascular quality was measured by the VQ-6 questionnaire, which was developed especially for clinical use in vascular registries, as the self-reported endpoints were essential to evaluate the outcome. The VQ-6 also provides a concise summary score that is practical to use as an index and suitable for incorporation into vascular registry systems. The action was recently introduced in the Swedish vascular registry (Swedvasc -http://www.ucr.uu.se/swedvasc/) (Nordanstig et al., 2014). The VQ-6 consisted of 6 items scored on a 4-point Likert scale, yielding total scores from 6 to 24, with higher scores indicating better vascular health (Larsen et al., 2020). The Indonesian version used in this study was translated and culturally adapted using standard forward–backward translation procedures reviewed by an expert panel. A pilot test confirmed that the Indonesian version was clear and comprehensible. The VQ-6 demonstrated good reliability (Cronbach's α = 0.82) and validity, with item correlations ranging from 0.56 to 0.78.

The Indonesian version of the Diabetic Neuropathy Symptom questionnaire (DNS-Ina) was used to assess peripheral diabetic neuropathy complaints. This questionnaire consists of 4 dichotomous (yes/no) questions regarding symptoms and signs of peripheral nerve dysfunction in diabetics over the past 2 weeks. The patients were categorized as having neuropathy if the score was >1 and as not having neuropathy if the score was 0. A previous study reported the reliability of the neurological score test for sensorimotor neuropathy assessment in type 2 DM patients, with 87% inter-rater reliability (Mardastuti et al., 2016). Although medical diagnostic examinations such as nerve conduction studies, electromyography, and monofilament testing are considered the gold standard, their use in large-scale field studies is limited by cost, time, and the need for specialized equipment and expertise (Tesfaye et al., 2010). The DNS has been widely validated as a reliable screening instrument for DPN, demonstrating good diagnostic performance compared with clinical and electrophysiological examinations. The DNS-Ina score had a sensitivity of 64.41% and a specificity of 80.95% (Herman et al., 2012; Mardastuti et al., 2016).

Diabetic neuropathy examination (DNE) was used to detect diabetic neuropathy using a reflex hammer, a 128Hz tuning fork, and a monofilament, with a sensitivity of 77.14% and a specificity of 77.78% (Amelia et al., 2019). The neurological deficits could be grouped into those due to enormous fiber damage and those due to slight fiber damage. The former deficits included decreased or lost ankle reflex response and vibration sensibility in the dorsal joint of the big toes. In contrast, the latter deficits were reduced or loss of sensation of pain and touch on the back of the foot. The DNE assessment has a maximum score of 16, indicating total sensory loss. The DNE scores >3 indicate positive neuropathy, while the scores <3 show negative neuropathy (Mardastuti et al., 2016; Pop-Busui et al., 2017). The neurological examinations for diabetic peripheral neuropathy were performed by trained physicians specializing in diabetes care and neurology, supported by trained research nurses.

2.4. Data analysis

Descriptive statistics provide frequencies and percentages for categorical variables and means and standard deviations for numerical variables. Statistical analysis was performed using SPSS version 21.0 for Windows. We compared the characteristics of participants with T2DM between the rural and urban groups using the chi-square test, independent-samples t-test, and Mann-Whitney test, with 95% confidence intervals. Multivariable logistic regression was used to identify DPN risk factors according to the recommended procedure (Hosmer et al., 2013). Significance level of <0.05 was used for all statistical tests.

2.5. Ethical consideration

This study obtained ethical approval from the Committee on Human Research Ethics, Faculty of Nursing, Universitas Airlangga (Ethical Approval No. 1591/KEPK). All participants were informed about the purpose, procedures, potential benefits, and risks of the study. Written informed consent was obtained from each participant prior to data collection, and their participation was voluntary. Participants were also assured of the confidentiality of their personal information and the right to withdraw at any time without any consequences.

3. Results

3.1. Characteristics of Participants

The results showed that more than 70% of participants were women in both urban and rural settings (Table 1). The mean age of the study population was 55.86(SD=8.378) years in rural areas, which was slightly younger than that of urban participants. The educational level of the participants was higher in urban than in rural areas (37.7% vs. 13.9% in the higher education level). People living in the city tended to engage in less regular physical activity (31.6% vs. 51.9%) and had higher fasting blood glucose levels (71.4% vs. 45.6%) than those living in the countryside. The duration of T2DM was similar between patients living in rural and urban areas (6.2 years vs. 5.9 years). These findings concluded that, among the sociodemographic characteristics, significant differences were observed in educational level, DM medication, physical activity, and fasting blood sugar levels between urban and rural participants.

Table 1. Sociodemographic characteristics of the participants (n=156)

Characteristics	Rural		Urban		*p*
	f(%)	Mean(SD)	f(%)	Mean(SD)	
Age (year)		55.86(8.378)		57.27(9.259)	0.319**
Gender					0.781*
Male	21 (26.6)		22 (28.6)		
Female	58 (73.4)		55 (71.4)		
Education level					0.001*
Low education	68 (86.1)		48 (62.3)		
Higher education	11 (13.9)		29 (37.7)		
Length of DM diagnosis (year)		6.23(5.724)		5.91(6.057)	0.670***
Cigarette use					0.108*
Yes	3 (3.8)		8 (10.4)		
No	76 (96.2)		69 (89.6)		
DM medication					0.001*
No medication	2 (2.5)		20 (25.9)		
Oral medication (OAD)	77 (97.5)		57 (74.1)		
Physical activities					0.010*
Regular	54 (68.4)		37 (48.1)		
Irregular	25 (31.6)		40 (51.9)		
Fasting blood sugar					0.001*
Normal (FCG < 126)	43 (54.4)		22 (28.6)		
High (FCG ≥ 126)	36 (45.6)		55 (71.4)		
Obesity					0.342*
Normal (BMI≤27)	52 (65.8)		45 (58.4)		
Obese (BMI> 27)	27 (34.2)		32 (41.6)		

Notes. *Chi-square test ** Independent Samples Test ***Mann Whitney test. Low education=no formal education and primary education. Higher education=secondary education and higher education.

3.2. Risk factors for DPN based on neuropathy-related signs and symptoms

As shown in Table 2, the risk factors for diabetic peripheral neuropathy (DPN) based on signs and symptoms in the vascular and peripheral nerves measured by using DNE, DNS, ABI, and VQ-6 were significantly different based on the place of residence ($p<0.05$), pointing out that rural residents had higher risks of DPN. The results showed that T2DM patients living in rural areas had significantly higher proportions of vascular impairment, as assessed by ABI (34.2%, $p=0.001$) and VQ-6 scores (70.9%, $p=0.020$), indicating a greater risk of peripheral arterial disease than urban participants. Table 2 also showed that respondents living in the village had more neuropathic symptoms according to DNS and DNE than those living in the city (69.6% vs. 48.1% and 43.1% vs. 24.7%, respectively).

Table 2. Risks of DPN based on the signs and symptoms of the vascular and peripheral nerves

Variables	Rural	Urban	*p*
Diabetic Neuropathy Symptoms (DNS)			.007*
Neuropathy negative symptoms	24 (30.4)	40 (51.9)	
Neuropathy positive symptoms	55 (69.6)	37 (48.1)	
Diabetic neuropathy examination (DNE)			.017*
Score 3 (neuropathy negative)	45 (56.9)	58 (75.3)	
Score >3 (positive neuropathy)	34 (43.1)	19 (24.7)	
Vascular Quality of Life Questionnaire (VQ-6)			.020*
Low risk	23 (29.1)	36 (46.7)	
High risk	56 (70.9)	41 (53.3)	
Ankle Brachial Index (ABI)			.001*
ABI >0.9	52 (65.8)	73 (94.8)	
ABI 0.9	27 (34.2)	4 (5.2)	

Notes. *Chi-square test

3.3. Factors associated with the risk of DPN

Based on multivariate logistic regression (Table 3), higher ABI (OR=17.07, 95%CI=4.22–69.01), more diabetic neuropathy symptoms (OR=3.35, 95%CI=1.35–8.32), more diabetes medications (OR=10.27, 95% CI=1.83–57.74), lower physical activity (OR=0.24, 95%CI=0.09–0.68), and lower education level (OR=0.25, 95%CI=0.10–0.60) were significantly associated with the risk of DPN ($p<0.05$). Conversely, diabetic neuropathy examination (DNE) and vascular quality of life (VQ-6) were not significantly associated in the final model. This study also found that ABI was the most significant risk factor for DPN in rural areas, with DM villagers with higher ABI 17.07 times more likely to experience DPN than urban residents.

Table 3. Factors associated with the risk of DPN among T2DM patients

	Variable	Coefficient (B)	*p*	OR (95%CI)
Step 1	ABI	2.776	0.001*	16.05 (3.92-65.64)
	Diabetic neuropathy symptoms (DNS)	1.224	0.009*	3.39 (1.36-8.49)
	Diabetic neuropathy examination (DNE)	.855	0.083	2.35 (0.89-6.17)
	Vascular Quality of Life Questionnaire	0.000	0.783	0.17 (0.07-0.44)
	Physical activity	-.425	0.341	0.65 (0.27-1.57)
	Level of education	-1.327	0.012*	0.27 (0.09-0.75)
	Fasting blood sugar	-1.340	0.003*	0.26 (0.11-0.64)
	DM medication consumption	2.303	0.008*	10.00 (1.84-54.53)
	Constant	-1.134	0.189	0.322
Step 2	ABI	2.837	0.001*	17.07 (4.22-69.01)
	Diabetic neuropathy symptoms (DNS)	1.209	0.009*	3.35 (1.35-8.32)
	Diabetic neuropathy examination (DNE)	0.821	0.092	2.27 (0.87-5.92)
	Vascular Quality of Life Questionnaire	0.001	0.783	0.17 (0.07-0.44)
	Physical activity	-1.410	0.007*	0.24 (0.09-0.68)
	Level of education	-1.399	0.002*	0.25 (0.10-0.60)
	DM medication consumption	2.330	0.008*	10.27 (1.83-57.74)
	Constant	-1.317	0.117	.268

Notes. *Significant at <0.05

4. Discussion

This study aimed to identify and compare the risk factors of diabetic peripheral neuropathy (DPN) among T2DM patients living in rural and urban areas of East Java, Indonesia. The main result was that the proportion of DPN based on signs and symptoms in the legs' vascular and peripheral nerves was higher in the rural T2DM population than in those living in urban areas. The findings also showed that both neuropathic symptoms (DNS, DNE) and vascular complications (ABI, VQ-6) were significantly associated with the place of residence, with rural participants showing a higher risk profile compared to urban participants. This is consistent with previous studies in developing countries, which reported that rural populations with T2DM often face higher risks of DPN (Nanayakkara et al., 2018; Tesfaye et al., 2010). This finding might be attributed to differences in lifestyle, access to healthcare services, and delayed detection of diabetes-related complications. Limited access to healthcare services often leads to delayed diagnosis, fewer routine screenings, and inadequate monitoring of glycemic status, allowing neuropathic damage to progress unchecked. Lower awareness and health literacy can reduce patients' ability to recognize early symptoms of neuropathy, adherence to medications, and self-care behaviors critical for preventing complications. Additionally, suboptimal diabetes control, often driven by financial constraints, irregular clinic visits, limited availability of diabetes education, and restricted access to laboratory testing, contributes to chronic hyperglycemia and microvascular injury, both of which accelerate neuropathy progression. These findings are consistent with studies from other developing countries, which demonstrate that rural T2DM populations have a higher risk of DPN due to structural, socioeconomic, and healthcare disparities (Nanayakkara et al., 2018; Tesfaye et al., 2010; Yang et al., 2025).

Surprisingly, based on the gender distribution in this study, almost two-thirds of the participants were women in urban and rural areas. This gender imbalance may have contributed to the observed differences in DPN proportions. Previous studies have reported that women with type 2 diabetes may experience higher rates of neuropathic symptoms and poorer quality of life related to neuropathy compared to men (Abdissa et al., 2020; Callaghan et al., 2015; Tesfaye et al., 2010). Several factors may explain this disparity. Hormonal influences, particularly changes in estrogen levels, can modulate nerve repair, inflammation, and pain perception, thereby increasing women's susceptibility to neuropathy (Yang et al., 2025). A study in Bangladesh found that women often do housework barefoot in water and do not consistently practice foot hygiene. Women are more at risk of experiencing DPN than men because of their work patterns (Banik et al., 2017), as almost all of the female respondents in the study were housewives. Longer life expectancy may also increase women's cumulative exposure to hyperglycemia and metabolic stress, increasing their risk for DPN (Hicks & Selvin, 2019). Additionally, differences in health-seeking behavior, with women being more likely to report symptoms and seek medical care, could increase detection rates of neuropathic symptoms (Rata Mohan et al., 2025).

The study found that rural patients had significantly higher impairment in ABI, DNS, and DNE scores compared to their urban counterparts. These disparities reflect persistent gaps in diabetes care between rural and urban populations. Rural areas often face limited healthcare infrastructure, fewer trained diabetes specialists, and reduced access to diagnostic tools. These factors delay early detection and management of diabetic complications. Additionally, rural residents generally have lower health literacy and less exposure to diabetes education programs, contributing to poorer glycemic control and greater progression of neuropathy and vascular impairment (Tai et al., 2020). Socioeconomic constraints, such as lower income and transportation barriers, further reduce the likelihood of routine check-ups and follow-up care. In contrast, urban residents typically benefit from easier access to healthcare facilities, structured diabetes education, and more consistent monitoring, resulting in earlier intervention and lower DPN severity. These rural-urban inequalities have been observed globally, underscoring that geographic disadvantage is an independent contributor to worsening diabetes outcomes (Foss et al., 2023; Mohamed et al., 2018).

The result also showed that T2DM patients in the village were more at risk of experiencing diabetic peripheral neuropathy (DPN) based on anamnesis of foot vascular complaints using VQ6 and ABI examination. Moreover, T2DM patients living in rural areas were 17.06 times more likely to exhibit abnormal vascular findings (ABI ≤ 0.9), indicating a higher risk of vascular impairment that may contribute to the development of DPN. Although ABI and VQ-6 primarily assess peripheral vascular status, vascular insufficiency has been shown to accelerate nerve ischemia and contribute to the development and progression of DPN. Therefore, the vascular abnormalities detected in rural participants reflect a higher overall risk profile for DPN (Hicks & Selvin, 2019; Pop-Busui et al., 2017). Vascular insufficiency at both the micro- and macrovascular levels has been shown to reduce blood flow and oxygen supply to peripheral nerves, thereby triggering axonal degeneration and increasing neuropathic damage, especially in patients with chronic hyperglycemia or peripheral arterial disease (Meena & C., 2019; Tesfaye et al., 2010). Although ABI is commonly used to detect peripheral arterial disease, in this study, it served as a relevant indicator of vascular involvement in DPN risk, while the VQ-6 was used to assess vascular quality; changes should be carefully recorded (Larsen et al., 2020). Overall, the high prevalence of vascular and neuropathic disorders in rural participants reflects a dual burden that increases the risk of DPN, exacerbated by limited access to healthcare, low education, and a lack of information about diabetes in the region (Agardh et al., 2011; Aung et al., 2018). These findings underscore the need for more intensive peripheral vascular evaluation in patients with T2DM, especially those aged 55 years and older and living in rural areas.

Other findings from this study, based on the results of history taking and physical examination using DNS and DNE, were consistent with previous studies, showing that rural residents had more signs and symptoms of neuropathy than those living in urban areas. A study reported that two out of ten T2DM subjects suffer from more severe peripheral neuropathy in rural areas due to poor hygiene conditions and more walking barefoot (Banik et al., 2017). This may be due to differences in populations, locations, settings, and tools used to determine DPN; hence, patients are referred with various complications and late disease diagnosis (Amour et al., 2019; Meena & C., 2019). DPN is established based on several types of examinations, namely history assessment, clinical symptoms, and physical examination (Pop-Busui et al., 2017). This study used the symptom score (DNS) and examination score (DNE), which were simple, reproducible, fast, and easy to perform for screening for neuropathy (Amelia et al., 2019). Early detection and early treatment can improve symptoms, reduce disease complications, and improve the quality of life of DM patients (Pratiwi et al., 2018; Zhao et al., 2016). Risk factor control and early detection need to be done to reduce the risk of DPN. We suggest that screening for signs and symptoms of T2DM be carried out in primary health services for patients in rural areas.

According to multivariate analysis, this study found that signs and symptoms of vascular disorders and neuropathy in the legs, lack of exercise, low education level, and use of DM medications were associated with a higher risk of developing DPN in T2DM patients in rural areas. The results were in line with previous studies pointing out that gender, having less education than college, having a longer duration of diabetes, and having foot examinations are associated with a higher risk of developing DPN (Liu et al., 2019; Zhao et al., 2016). DM patients diagnosed for 5 years should undergo regular examinations to screen for DPN (Jiao et al., 2016). It is crucial to investigate further why there is a high risk of neuropathy in rural residents, especially by evaluating the diabetes management of T2DM patients in rural areas. We underline the importance of educating rural communities about DM management, early detection, and the prevention of severe complications, especially in the legs.

5. Implication and limitation

This study highlights the critical role of nurses in addressing disparities in diabetes care, particularly in rural areas. By strengthening early detection, providing education tailored to patients' literacy levels, and supporting adherence to lifestyle and treatment regimens, nurses can significantly reduce the risk and burden of DPN. These efforts are essential not only for improving clinical outcomes but also for enhancing the long-term quality of life of people with T2DM living in rural communities. Moreover, this research's findings emphasize the need for baseline data on regional differences in risk factors.

The main limitation of this study is that the sample may not fully represent all T2DM patients, as data were collected during daytime hours on weekdays. This may have led to an underrepresentation of working adults, particularly men, potentially affecting the generalizability of the findings. Another limitation is the cross-sectional design, which does not allow for causal inferences between sociodemographic factors, clinical variables, and the risk of DPN. Longitudinal studies are thereby needed to confirm these associations over time.

6. Conclusion

Based on DNE, DNS, ABI, and VQ-6 parameters, people with T2DM living in rural areas had a higher risk of developing DPN than those in urban areas, with ABI as the most significant contributing factor. Other factors that triggered the high risk of DPN in rural areas included persons who lacked sports activities, had low education levels, and were on DM medication. The vulnerable populations identified by this study underscore the importance of early detection and education programs for DPN prevention and management, particularly in rural areas. Future research should explore intervention models that integrate lifestyle modification and vascular health monitoring into comprehensive DPN prevention strategies.

Acknowledgments

We express our deepest gratitude to Universitas Airlangga, the funder of this research, and to all participants and parties involved in the research. This study was supported by Universitas Airlangga, Indonesia, in 2019 with Grant Number: 1523/UN3.1.13/LT/2019.

Author contribution

AQ led the research and was responsible for conceiving and designing the analysis. INP contributed to data analysis. LNY collected the data. ZP and ETP drafted the manuscript. NN and VR provided critical revisions and contributed to improving the manuscript. All authors read and approved the final version.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Abdissa, D., Adugna, T., Gerema, U., & Dereje, D. (2020). Prevalence of diabetic foot ulcer and associated factors among adult diabetic patients on follow-up clinic at Jimma Medical Center, Southwest Ethiopia, 2019: An institutional-based cross-sectional study. *Journal of Diabetes Research*, *2020*, 4106383. https://doi.org/10.1155/2020/4106383

Aboyans, V., Ricco, J.-B., Bartelink, M.-L. E. L., Björck, M., Brodmann, M., Cohnert, T., Collet, J.-P., Czerny, M., De Carlo, M., Debus, S., Espinola-Klein, C., Kahan, T., Kownator, S., Mazzolai, L., Naylor, A. R., Roffi, M., Röther, J., Sprynger, M., Tendera, M., ... Desormais, I. (2018). 2017 ESC guidelines on the diagnosis and treatment of peripheral arterial diseases, in collaboration with the European Society for Vascular Surgery (ESVS): Document covering atherosclerotic disease of extracranial carotid and vertebral, mesenteric, renal. *European Heart Journal*, *39*(9), 763–816. https://doi.org/10.1093/eurheartj/ehx095

Agardh, E., Allebeck, P., Hallqvist, J., Moradi, T., & Sidorchuk, A. (2011). Type 2 diabetes incidence and socioeconomic position: A systematic review and meta-analysis. *International Journal of Epidemiology*, *40*(3), 804–818. https://doi.org/10.1093/ije/dyr029

Agnez, A., Aska, A., & Wardhani, M. K. (2025). Duration of diabetes, glycemic control, and risk of neuropathy among diabetes population in Indonesia. *Innovation in Health for Society, 5*(2), 79–88. https://doi.org/10.31603/ihs.13073

Aleidan, F. A. S., Ahmad, B. A., Alotaibi, F. A., Aleesa, D. H., Alhefdhi, N. A., Badri, M., & Abdel Gader, A. G. (2020). Prevalence and risk factors for diabetic peripheral neuropathy among Saudi hospitalized diabetic patients: A nested case-control study. *International Journal of General Medicine*, *13*, 881–889. https://doi.org/10.2147/IJGM.S273807

Amelia, R., Burhan, B., & Lelo, A. (2018). The relationship between anthropometry and ankle-brachial index with blood glucose level in patients with type 2 diabetes mellitus at the community health center in Medan, Indonesia. *Family Medicine and Primary Care Review*, *20*(4), 307–312. https://doi.org/10.5114/fmpcr.2018.79339

Amelia, R., Wahyuni, A. S., & Yunanda, Y. (2019). Diabetic neuropathy among type 2 diabetes mellitus patients at Amplas primary health care in Medan city. *Open Access Macedonian Journal of Medical Sciences*, *7*(20), 3400–3403. https://doi.org/10.3889/oamjms.2019.433

American Diabetes Association. (2010). Standards of medical care in diabetes. *Diabetic Retinopathy*, 1–36. https://doi.org/10.1142/9789814304443_0001

American Diabetes Association. (2023). *American Diabetes Association releases 2023 standards of care in diabetes to guide prevention, diagnosis, and treatment for people living with diabetes*. American Diabetes Association. https://diabetes.org/newsroom/american-diabetes-association-2023-standards-care-diabetes-guide-for-prevention-diagnosis-treatment-people-living-with-diabetes

Amour, A. A., Chamba, N., Kayandabila, J., Lyaruu, I. A., Marieke, D., Shao, E. R., & Howlett, W. (2019). Prevalence, patterns, and factors associated with peripheral neuropathies among diabetic patients at tertiary hospital in the Kilimanjaro Region: Descriptive cross-sectional study from North-Eastern Tanzania. *International Journal of Endocrinology*, *2019,* 5404781. https://doi.org/10.1155/2019/5404781

Aung, W. P., Htet, A. S., Bjertness, E., Stigum, H., Chongsuvivatwong, V., & Kjøllesdal, M. K. R. (2018). Urban-rural differences in the prevalence of diabetes mellitus among 25-74 year-old adults of the Yangon Region, Myanmar: Two cross-sectional studies. *BMJ Open*, *8*(3), 1–9. https://doi.org/10.1136/bmjopen-2017-020406

Banik, P., Bhowmik, N., Moniruzzaman, M., Zaman, F., & Ali, L. (2017). *Prevalence and determinants of peripheral neuropathy among urban and rural Bangladeshi type 2 diabetic subjects*. IDF Congress 2017. https://doi.org/10.13140/RG.2.2.22790.68165

Callaghan, B., Kerber, K., Langa, K. M., Banerjee, M., Rodgers, A., McCammon, R., Burke, J., & Feldman, E. (2015). Longitudinal patient-oriented outcomes in neuropathy: Importance of early detection and falls. *Neurology*, *85*(1), 71–79. https://doi.org/10.1212/WNL.0000000000001714

Contesa, A., Malini, H., & Rahman, D. (2025). Comprehensive risk analysis of diabetic peripheral neuropathy in type II diabetes mellitus. *Journal of Diabetes and Metabolic Disorders*, *24*(1), 123. https://doi.org/10.1007/s40200-025-01630-8

Curry, S. J., Krist, A. H., Owens, D. K., Barry, M. J., Caughey, A. B., Davidson, K. W., Doubeni, C. A., Epling, J. W., Kemper, A. R., Kubik, M., Landefeld, C. S., Mangione, C. M., Silverstein, M., Simon, M. A., Tseng, C. W., & Wong, J. B. (2018). Screening for peripheral artery disease and cardiovascular disease risk assessment with the Ankle-Brachial Index: US preventive services task force recommendation statement. *JAMA- Journal of the American Medical Association*, *320*(2), 177–183. https://doi.org/10.1001/jama.2018.8357

Dai, K.-S., Tai, D.-Y., Ho, P., Chen, C.-C., Peng, W.-C., Chen, S.-T., Hsu, C.-C., Liu, Y.-P., Hsieh, H.-C., Yang, C.-C., Tsai, M.-C., & Mao, S. J. T. (2004). Accuracy of the EasyTouch blood glucose self-monitoring system: A study of 516 cases. *Clinica Chimica Acta; International Journal of Clinical Chemistry*, *349*(1–2), 135–141. https://doi.org/10.1016/j.cccn.2004.06.010

Daniel, W. W., & Cross, C. L. (2013). *Biostatistics: A foundation for analysis in the health sciences* (10th Ed.). Library of Congress Cataloging.

Deepa, M., Bhansali, A., Anjana, R., Pradeepa, R., Joshi, S., Joshi, P., Dhandhania, V., Rao, P., Subashini, R., Unnikrishnan, R., Shukla, D., Madhu, S., Das, A., Mohan, V., & Kaur, T. (2014). Knowledge and awareness of diabetes in urban and rural India: The Indian Council of Medical Research India diabetes study (Phase I): Indian Council of Medical Research India Diabetes 4. *Indian Journal of Endocrinology and Metabolism*, *18*(3), 379–385. https://doi.org/10.4103/2230-8210.131191

Elafros, M. A., Andersen, H., Bennett, D. L., Savelieff, M. G., Viswanathan, V., Callaghan, B. C., & Feldman, E. L. (2022). Towards prevention of diabetic peripheral neuropathy: Clinical presentation, pathogenesis, and new treatments. *The Lancet. Neurology*, *21*(10), 922–936. https://doi.org/10.1016/S1474-4422(22)00188-0

Elfil, M., & Negida, A. (2017). Sampling methods in clinical research; An educational review. *Emergency*, *5*(1), e52.

Etikan, I. (2017). Sampling and sampling methods. *Biometrics & Biostatistics International Journal*, *5*(6), 215–217. https://doi.org/10.15406/bbij.2017.05.00149

Foss, R., Fischer, K., Lampman, M. A., Laabs, S., Halasy, M., Allen, S. V., Garrison, G. M., Sobolik, G., Bernard, M., Sosso, J., & Thacher, T. D. (2023). Disparities in diabetes care: Differences between rural and urban patients within a large health system. *Annals of Family Medicine*, *21*(3), 234–239. https://doi.org/10.1370/afm.2962

Gerhard-Herman, M. D., Gornik, H. L., Barrett, C., Barshes, N. R., Corriere, M. A., Drachman, D. E., Fleisher, L. A., Fowkes, F. G. R., Hamburg, N. M., Kinlay, S., Lookstein, R., Misra, S., Mureebe, L., Olin, J. W., Patel, R. A. G., Regensteiner, J. G., Schanzer, A., Shishehbor, M. H., Stewart, K. J., … Walsh, M. E. (2017). 2016 AHA/ACC guideline on the management of patients with lower extremity peripheral artery disease: A report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines. *Circulation*, *135*(12), e726–e779. https://doi.org/10.1161/CIR.0000000000000471

Govindarajan Venguidesvarane, A., Jasmine, A., Varadarajan, S., Shriraam, V., Muthuthandavan, A. R., Durai, V., Thiruvengadam, G., & Mahadevan, S. (2020). Prevalence of vascular complications among type 2 diabetic patients in a rural health center in South India. *Journal of Primary Care and Community Health*, *11*(1), 2150132720959962. https://doi.org/10.1177/2150132720959962

Herman, W. H., Pop-Busui, R., Braffett, B. H., Martin, C. L., Cleary, P. A., Albers, J. W., & Feldman, E. L. (2012). Use of the Michigan neuropathy screening instrument as a measure of distal symmetrical peripheral neuropathy in type 1 diabetes: Results from the diabetes control and complications trial/epidemiology of diabetes interventions and complications. *Diabetic Medicine: A Journal of the British Diabetic Association*, *29*(7), 937–944. https://doi.org/10.1111/j.1464-5491.2012.03644.x

Hicks, C. W., & Selvin, E. (2019). Epidemiology of peripheral neuropathy and lower extremity disease in diabetes. *Current Diabetes Reports*, *19*(10), 86. https://doi.org/10.1007/s11892-019-1212-8

Hosmer, D. W., Lemeshow, S., & Sturdivant, R. X. (2013). *Applied Logistic Regression* (3rd ed.). Wiley. https://dl.icdst.org/pdfs/files4/7751d268eb7358d3ca5bd88968d9227a.pdf

Indonesian Society of Endocrinology. (2021). *Pedoman pengelolaan dan pencegahan diabetes melitus tipe 2 dewasa di Indonesia* [Guidelines for management and prevention of type 2 diabetes mellitus adults in Indonesia]. The Indonesian Society of Endocrinology. https://www.ginasthma.org.

International Diabetes Federation. (2025). *IDF diabetes atlas*. International Diabetes Federation. https://diabetesatlas.org/resources/idf-diabetes-atlas-2025/
Jiao, H., Kulyté, A., Näslund, E., Thorell, A., Gerdhem, P., Kere, J., Arner, P., & Dahlman, I. (2016). Whole-exome sequencing suggests LAMB3 as a susceptibility gene for morbid obesity. *Diabetes*, *65*(10), 2981–2989. https://doi.org/10.2337/db16-0522
Kadam, P., & Bhalerao, S. (2010). Sample size calculation. *International Journal of Ayurveda Research*, *1*(1), 55–57. https://doi.org/10.4103/0974-7788.59946
Katulanda, P., Ranasinghe, P., Jayawardena, R., Constantine, G. R., Sheriff, M. H. R., & Matthews, D. R. (2012). The prevalence, patterns, and predictors of diabetic peripheral neuropathy in a developing country. *Diabetology and Metabolic Syndrome*, *4*(1), 1–8. https://doi.org/10.1186/1758-5996-4-21
Larsen, A. S. F., Reiersen, A. T., Jacobsen, M. B., Kløw, N. E., Nordanstig, J., Morgan, M., & Wesche, J. (2017). Validation of the Vascular quality of life questionnaire-6 for clinical use in patients with lower limb peripheral arterial disease. *Health and Quality of Life Outcomes*, *15*(1), 184. https://doi.org/10.1186/s12955-017-0760-3
Larsen, A. S. F., Reiersen, A. T., Nådland, I. H., & Wesche, J. (2020). Self-reported health status and disease-specific quality of life one year after treatment for peripheral arterial disease in clinical practice. *Health and Quality of Life Outcomes*, *18*(1), 1–8. https://doi.org/10.1186/s12955-020-01477-y
Lee, H. Y., Won, J. C., Kang, Y. J., Yoon, S. H., Choi, E. O., Bae, J. Y., Sung, M. H., Kim, H. R., Yang, J. H., Oh, J., Lee, Y. M., Park, N. H., Ko, K. S., & Rhee, B. D. (2010). Type 2 diabetes in urban and rural districts in Korea: Factors associated with prevalence difference. *Journal of Korean Medical Science*, *25*(12), 1777–1783. https://doi.org/10.3346/jkms.2010.25.12.1777
Leyrat, C., Eldridge, S., Taljaard, M., & Hemming, K. (2024). Practical considerations for sample size calculation for cluster randomized trials. *Journal of Epidemiology and Population Health*, *72*(1), 202198. https://doi.org/10.1016/j.jeph.2024.202198
Liu, X., Xu, Y., An, M., & Zeng, Q. (2019). The risk factors for diabetic peripheral neuropathy: A meta-analysis. *PLoS ONE*, *14*(2), 1–16. https://doi.org/10.1371/journal.pone.0212574
Lwanga, S., & Lemeshow, S. (1991). *Sample Size Determination in Health Studies*. A practical manual. World Health Organization. http://www.tbrieder.org/publications/books_english/lemeshow_samplesize.pdf
Lutfiyya, M. N., McCullough, J. E., Mitchell, L., Dean, L. S., & Lipsky, M. S. (2011). Adequacy of diabetes care for older U.S. rural adults: A cross-sectional population-based study using 2009 BRFSS data. *BMC Public Health*, *11*, 13–16. https://doi.org/10.1186/1471-2458-11-940
Makwana, D., Engineer, P., Dabhi, A., & Chudasama, H. (2023). Sampling methods in research: A review. *Journal of Trend in Scientific Research and Development (IJTSRD), 7*(3), 762–768.
Malik, R. A., Andag-Silva, A., Dejthevaporn, C., Hakim, M., Koh, J. S., Pinzon, R., Sukor, N., & Wong, K. S. (2020). Diagnosing peripheral neuropathy in South-East Asia: A focus on diabetic neuropathy. *Journal of Diabetes Investigation*, *11*(5), 1097–1103. https://doi.org/10.1111/jdi.13269
Mardastuti, Y., Asmedi, A., & Gofir, A. (2016). Diabetic neuropathy symptom-versi Indonesia dan diabetic neuropathy examination-versi Indonesia sebagai skor diagnostik [Diabetic neuropathy symptoms and diabetic neuropathy examination-Indonesian version as diagnostic scores]. *Berkala Neurosains*, *15*(2), 55–65. https://doi.org/10.22146/BNS.V15I2.55750
Meena, S., & C., M. R. (2019). Prevalence of peripheral neuropathy and peripheral artery disease in diabetic patients attending a tertiary care hospital. *International Journal of Advances in Medicine*, *6*(5), 1493. https://doi.org/10.18203/2349-3933.ijam20194137
Mekuria-Negussie, Y., & Tilahun-Bekele, N. (2024). Diabetic peripheral neuropathy among adult type 2 diabetes patients in Adama, Ethiopia: health facility-based study. *Scientific Reports*, *14*(1), 3844. https://doi.org/10.1038/s41598-024-53951-y
Miller, C. A. (2012). *Nursing for wellness in older adults* (6th ed.). Lippincott Williams & Wilkins, Wolter Kluwer Health.
Ministry of Health, Republic of Indonesia. (2018). *Laporan riset kesehatan dasar provinsi Jawa Timur 2018 [Basic health research report, East Java province, year 2018]*. National Institute of Health Research and Development.

https://repository.badankebijakan.kemkes.go.id/id/eprint/3901/

Mohamed, S. F., Mwangi, M., Mutua, M. K., Kibachio, J., Hussein, A., Ndegwa, Z., Owondo, S., Asiki, G., & Kyobutungi, C. (2018). Prevalence and factors associated with pre-diabetes and diabetes mellitus in Kenya: results from a national survey. *BMC Public Health*, *18*(Suppl 3), 1215. https://doi.org/10.1186/s12889-018-6053-x

Mørkrid, K., Ali, L., & Hussain, A. (2010). Risk factors and prevalence of diabetic peripheral neuropathy: A study of type 2 diabetic outpatients in Bangladesh. *International Journal of Diabetes in Developing Countries*, *30*(1), 11–17. https://doi.org/10.4103/0973-3930.60004

Nanayakkara, N., Ranasinha, S., Gadowski, A., Heritier, S., Flack, J. R., Wischer, N., Wong, J., & Zoungas, S. (2018). Age, age at diagnosis, and diabetes duration are all associated with vascular complications in type 2 diabetes. *Journal of Diabetes and Its Complications*, *32*(3), 279–290. https://doi.org/10.1016/j.jdiacomp.2017.11.009

National Institute of Health Research and Development. (2018). *Buku pedoman pengisian kuesioner Riskesdas 2018 [Guideline book to fill the 2018 basic health research questionnaires]*. Ministry of Health, Republic of Indonesia. https://repository.badankebijakan.kemkes.go.id/id/eprint/4606/1/Pedoman_Kues_Rkd_2018_1.pdf

Noor, S., Khan, R. U., & Ahmad, J. (2017). Understanding diabetic foot infection and its management. *Diabetes and Metabolic Syndrome: Clinical Research and Reviews*, *11*(2), 149–156. https://doi.org/10.1016/j.dsx.2016.06.023

Nordanstig, J., Wann-Hansson, C., Karlsson, J., Lundström, M., Pettersson, M., & Morgan, M. B. F. (2014). Vascular quality of life questionnaire-6 facilitates health-related quality of life assessment in peripheral arterial disease. *Journal of Vascular Surgery*, *59*(3), 700-707.e1. https://doi.org/10.1016/j.jvs.2013.08.099

O'Connor, A., & Wellenius, G. (2012). Rural–urban disparities in the prevalence of diabetes and coronary heart disease. *Public Health*, *126*(10), 813–820. https://doi.org/https://doi.org/10.1016/j.puhe.2012.05.029

Polit, D. F., & Beck, C. T. (2017). *Nursing research: Generating and assessing evidence for nursing practice*. Lippincott Williams and Wilkins.

Pop-Busui, R., Boulton, A. J. M., Feldman, E. L., Bril, V., Freeman, R., Malik, R. A., Sosenko, J. M., & Ziegler, D. (2017). Diabetic neuropathy: A position statement by the American diabetes association. *Diabetes Care*, *40*(1), 136–154. https://doi.org/10.2337/dc16-2042

Pratiwi, I. N., Pawanis, Z., Hidayati, L., Widyawati, I. Y., Ni'Mah, L., Sukartini, T., Bakar, A., & Mariyanti, H. (2018). The role of a healthy-eating educational module during Ramadan in a community health centre. *Journal of Diabetes Nursing*, *22*(2), Article JDN013.

Rahmawati, A., & Hargono, A. (2018). Dominant factor of diabetic neuropathy on diabetes mellitus type 2 patients. *Jurnal Berkala Epidemiologi*, *6*(1), 60. https://doi.org/10.20473/jbe.v6i12018.60-68

Ramalivhana, F. W., Veldsman, T., & Moss, S. J. (2024). Assessment of non-communicable disease risk factors, functional performance, and health-related quality of life in adults: a comparative analysis in low-resourced urban and rural areas of South Africa. *BMC Public Health*, *24*(1), 1580. https://doi.org/10.1186/s12889-024-18964-2

Rata Mohan, D. S., Jawahir, S., Manual, A., Abdul Mutalib, N. E., Mohd Noh, S. N., Ab Rahim, I., Ab Hamid, J., & Amer Nordin, A. (2025). Gender differences in health-seeking behaviour: Insights from the National Health and Morbidity Survey 2019. *BMC Health Services Research*, *25*(1), 900. https://doi.org/10.1186/s12913-025-13020-0

Setia, M. S. (2016). Methodology series module 3: Cross-sectional studies. *Indian Journal of Dermatology*, *61*(3), 261–264. https://doi.org/10.4103/0019-5154.182410

Soewondo, P., Ferrario, A., & Tahapary, D. L. (2013). Challenges in diabetes management in Indonesia: a literature review. *Globalization and Health*, *9*, 63. https://doi.org/10.1186/1744-8603-9-63

Sun, H., Saeedi, P., Karuranga, S., Pinkepank, M., Ogurtsova, K., Duncan, B. B., Stein, C., Basit, A., Chan, J. C. N., Mbanya, J. C., Pavkov, M. E., Ramachandaran, A., Wild, S. H., James, S., Herman, W. H., Zhang, P., Bommer, C., Kuo, S., Boyko, E. J., & Magliano, D. J. (2022). IDF diabetes atlas: Global, regional and country-level diabetes prevalence estimates for 2021 and projections for 2045. *Diabetes Research and Clinical Practice*, *183*, 109119. https://doi.org/10.1016/j.diabres.2021.109119

Sun, M., Sun, X., Wang, F., & Liu, L. (2025). Machine learning-based prediction of diabetic peripheral neuropathy: model development and clinical validation. *Frontiers in Endocrinology*, *16*, 1614657. https://doi.org/10.3389/fendo.2025.1614657

Susanti, I., Maria Seraph, N., Natasya Edward, M., & Burhan, A. (2025). National trends in the prevalence of diabetic peripheral neuropathy among diabetes mellitus patients in Indonesia (2010–2024): A pooled meta-analysis of 46 Studies with 2,808 Participants. *Java Nursing Journal*, *3*(2), 124–146. https://doi.org/10.61716/jnj.v3i2.103

Tai, S. Y., He, J. S., Kuo, C. T., & Kawachi, I. (2020). Urban–rural disparities in the incidence of diabetes-related complications in Taiwan: A propensity score matching analysis. *Journal of Clinical Medicine*, *9*(9), 1–12. https://doi.org/10.3390/jcm9093012

Talukder, A., Sara, S. S., Hossain, M. T., Nath, C. D., Rahman, R., Hussain, S., Sarma, H., & Huda, M. N. (2024). Rural and urban differences in the prevalence and determinants of Type-2 diabetes in Bangladesh. *PLOS ONE*, *19*(4), e0298071. https://doi.org/10.1371/journal.pone.0298071

Tesfaye, S., Boulton, A. J. M., Dyck, P. J., Freeman, R., Horowitz, M., Kempler, P., Lauria, G., Malik, R. A., Spallone, V., Vinik, A., Bernardi, L., & Valensi, P. (2010). Diabetic neuropathies: update on definitions, diagnostic criteria, estimation of severity, and treatments. *Diabetes Care*, *33*(10), 2285–2293. https://doi.org/10.2337/dc10-1303

The Central Bureau of Statistics Lamongan regency. (2021). *Kabupaten Lamongan dalam angka 2021* [Lamongan regency in figures 2021]. The Central Bureau of Statistics Lamongan regency.https://lamongankab.bps.go.id/id/publication/2021/02/26/28b8635a338b571c7b2500b3/kabupaten-lamongan-dalam-angka-2021.html

The Central Bureau of Statistics Surabaya. (2021). *Kota Surabaya dalam angka 2021* [Surabaya Municipality in figures 2021]. The Central Bureau of Statistics Surabaya. https://surabayakota.bps.go.id/id/publication/2021/02/26/b211aaf09579fe2603e56d0f/kota-surabaya-dalam-angka-2021.html

Tripathy, J. P., Thakur, J. S., Jeet, G., Chawla, S., Jain, S., Pal, A., Prasad, R., & Saran, R. (2017). Prevalence and risk factors of diabetes in a large community-based study in North India: results from a STEPS survey in Punjab, India. *Diabetology & Metabolic Syndrome*, *9*, 8. https://doi.org/10.1186/s13098-017-0207-3

Wahidin, M., Achadi, A., Besral, B., Kosen, S., Nadjib, M., Nurwahyuni, A., Ronoatmodjo, S., Rahajeng, E., Pane, M., & Kusuma, D. (2024). Projection of diabetes morbidity and mortality till 2045 in Indonesia based on risk factors and NCD prevention and control programs. *Scientific Reports*, *14*(1), 5424. https://doi.org/10.1038/s41598-024-54563-2

Wang, Y., Zhang, Y., Guo, T., Han, J., & Fu, G. (2024). Knowledge level and health information-seeking behavior of people with diabetes in rural areas: a multicenter cross-sectional study. *Frontiers in Public Health*, *12*(May), 1–10. https://doi.org/10.3389/fpubh.2024.1285114

Yang, Y., Zhang, L., Wang, H., Zhao, J., Liu, J., Chen, Y., Lu, J., Duan, Y., Hu, H., Peng, H., & Ye, L. (2024). Development and validation of a risk prediction model for invasiveness of pure ground-glass nodules based on a systematic review and meta-analysis. *BMC Medical Imaging*, *24*(1), 149. https://doi.org/10.1186/s12880-024-01313-5

Yang, Y., Zhao, B., Wang, Y., Lan, H., Liu, X., Hu, Y., & Cao, P. (2025). Diabetic neuropathy: cutting-edge research and future directions. *Signal Transduction and Targeted Therapy*, *10*(1), 132. https://doi.org/10.1038/s41392-025-02175-1

Yang, Z., Chen, R., Zhang, Y., Huang, Y., Hong, T., Sun, F., Ji, L., & Zhan, S. (2018). Scoring systems to screen for diabetic peripheral neuropathy. *Cochrane Database of Systematic Reviews*, *2018*(7), 2–5. https://doi.org/10.1002/14651858.CD010974.pub2

Zhao, M., Lin, H., Yuan, Y., Wang, F., Xi, Y., Wen, L., Shen, P., & Bu, S. (2016). Prevalence of pre-diabetes and its associated risk factors in rural areas of Ningbo, China. *International Journal of Environmental Research and Public Health*, *13*(8), 808. https://doi.org/10.3390/ijerph13080808