ORIGINAL RESEARCH

Duration of diabetes, glycemic control, and risk of neuropathy among diabetes population in Indonesia

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Abstract

Diabetic neuropathy is a serious and common complication for individuals with Type 2 Diabetes (T2D). However, there's a scarcity of studies investigating how the duration of diabetes and glycemic control impact the development of neuropathy. This study aimed to examine the effect of diabetes duration and blood glucose levels on the risk of neuropathy in patients with T2D in Surabaya. This was an observational study utilizing a cross-sectional data collection method. Data were gathered from 150 patients between May and July 2023. Patients were categorized based on their diabetes duration (less than 5 years, 5–10 years, and greater than 10 years) and their blood glucose levels (HbA1c less than 7%, 7–10%, and greater than 10%). Neuropathy was assessed using the 10g monofilament test and the Neuropathy Disability Score (NDS). Statistical analysis involved descriptive statistics and logistic regression, with a significance level set at 0.05 for hypothesis testing. The results revealed a significantly higher risk of neuropathy in patients with T2D for more than 10 years (90%) compared to those with T2D for less than 5 years (40%). Similarly, patients with poor blood glucose control (HbA1c greater than 10%) had an 85% chance of developing neuropathy. Whereas only 30% of those with well-controlled blood glucose (HbA1c less than 7%) developed the condition. Logistic regression analysis further confirmed that both a longer diabetes duration and elevated blood glucose levels significantly increase the risk of neuropathy (p<0.05). These findings underscore the critical importance of effective blood glucose management and early neuropathy detection to prevent severe diabetic complications. Furthermore, this study highlights the urgent need for enhanced diabetes education, early screening programs, and improved healthcare strategies across Indonesia to mitigate the burden of diabetic neuropathy.

Keywords: Duration of diabetes, endocrinology, glycemic control, innovation in health, type 2 diabetes

Introduction

Diabetes poses a significant global health burden that impacting millions of individuals around the world (Hossain et al., 2024). The global diabetes prevalence in 2019 is estimated to be 9.3% (463 million people), rising to 10.2% (578 million) by 2030 and 10.9% (700 million) by 2045 (Saeedi et al., 2019). Among the different types of diabetes, Type 2 Diabetes (T2D) is the most common in the population (Reed et al., 2021). The worldwide prevalence of type 2 diabetes is anticipated to reach 7079 individuals per 100.000 by the year 2030 that indicating a persistent increase across all global regions (Khan et al., 2020). T2D happens when the body becomes resistant to insulin or does not produce enough insulin that leading to high blood glucose levels (Galicia-Garcia et al., 2020). One of the most common and serious complications of T2D is diabetic neuropathy (Galiero et al., 2023). This condition occurs when high blood glucose damages the nerves, especially in the feet and legs (Smith et al., 2022). People may initially experience tingling, numbness, or pain, especially at night, and if left unchecked, the nerve damage can worsen over time, leading to serious complications (Feldman et al., 2019). A study shows that approximately 8% of people have neuropathy at the time of diabetes diagnosis, and this prevalence increases to around 50% after 25 years of living with diabetes (Pfannkuche et al., 2020).

Understanding what causes diabetic neuropathy is very important for healthcare professionals particularly in developing countries (Misra et al., 2019). Many studies have found that the risk of neuropathy increases with longer diabetes duration, high blood glucose levels, age, gender, and lifestyle factors (Liu et al., 2019; Braffett et al., 2020). Keeping blood glucose under control with measuring HbA1c levels is one of the best ways to reduce the risk of complications like neuropathy (Nozawa et al., 2022). In fact, lowering HbA1c by just 1% can reduce the risk of small blood vessel complications by 37% (Pozzilli et al., 2014). However, in many developing countries, regular blood glucose monitoring and proper management of neuropathy are still not widely available **(Figure 1)**. Surabaya has the highest

Figure 1. Insulin injection as glycemic control for patients with T2D (Courtesy of www.unsplash.com).

number of people with Diabetes Mellitus and has experienced an increase from 102.599 in 2017 to 115.460 in 2018 (Bestari, 2020). Many of them suffer from complications, including diabetic neuropathy. To manage this problem, the local government has introduced programs such as health education, free diabetes screenings, and medication support. However, the effectiveness of these programs is still unclear, and many people continue to struggle with poor diabetes management. Even though studies on diabetes and neuropathy exist as mentioned above, there is still a lack of research that focuses on how diabetes duration and blood glucose levels are linked to neuropathy in Surabaya.

Moreover, this study highlights critical gaps that previous research may not have adequately explored within the Indonesian context. Furthermore, while general associations between diabetes and neuropathy are known, the absence of specific, localized data on how prolonged exposure to hyperglycemia (duration) and the degree of blood glucose control (glycemic control) influence neuropathy risk in Indonesia is a significant void. Understanding these factors can help doctors and healthcare workers create better prevention and treatment strategies (Golovaty et al., 2023). For this reason, this study aims to examine the relationship between diabetes duration, blood glucose levels, and the risk of diabetic neuropathy among patients with T2D in Surabaya. It is expected that the finding of this study can help improve healthcare services, prevent complications, and improve the quality of life for people with T2D in Indonesia. This study holds significant importance primarily because it addresses a critical health issue – diabetic neuropathy, a debilitating complication – within a specific and relevant demographic: the Indonesian diabetes population. Focusing on Indonesia provides localized evidence that is crucial for generating public health strategies. Understanding the precise impact of diabetes duration and glycemic control allows healthcare providers and policymakers to better identify high-risk individuals and prioritize interventions (American Diabetes Association Professional Practice Committee, 2022). This also enables them to allocate resources effectively for the prevention and early management of neuropathy (Blaibel et al., 2024). This is especially vital given the potential variations in genetic susceptibility, lifestyle, dietary habits, and healthcare access that might exist in the Indonesian population compared to Western countries.

Method

This study employed an observational design with a cross-sectional method to achieve its objectives. This means that researchers observed and collected data from a specific group of patients at a single point in time, rather than following them over a period or actively intervening (Setia, 2016). This approach provides a "snapshot" of the prevalence of neuropathy in relation to diabetes duration and glycemic control within the study population at that particular moment. It is a cost-effective and relatively quick method for identifying associations and generating hypotheses which making it suitable for exploring the relationship between variables. However, a key limitation of this design is that it cannot establish a definitive cause-and-effect relationship between diabetes duration/glycemic control and neuropathy, as it doesn't track changes or outcomes over time (Boyko, 2013). The study examines how the length of time a person has diabetes and their blood glucose levels affect the risk of neuropathy in patients with T2D in Surabaya. The study included patients with type 2 diabetes who were receiving treatment at healthcare facilities in Surabaya. The inclusion criteria were: patients diagnosed with T2D based on American Diabetes Association (ADA) standards, aged 18 years or older, and willing to give informed consent. Patients were excluded if they had other conditions that could cause neuropathy, such as alcoholic neuropathy, or if they had acute diabetes complications. The sample was selected using consecutive sampling, meaning all eligible patients were included until the total number reached 150.

The study measured several variables as follows the independent variables were diabetes duration (categorized as less than 5 years, 5–10 years, and more than 10 years) and blood glucose levels (HbA1c categorized as less than 7%, 7–10%, and more than 10%). The dependent variable was neuropathy that assessed using the 10g monofilament test and the Neuropathy Disability Score (NDS). All the instruments were validated by researchers before being used. The 10g monofilament test measured the ability to feel light pressure on the feet (Hazari et al., 2024). While the NDS evaluated reflexes, vibration sense, and temperature sensation to determine the severity of nerve damage (Yang et al., 2018).

Additional data, including patient demographics, medical history, and lifestyle factors, were collected through interviews, clinical examinations, and medical records. The entire data collection process was conducted by the researchers and research assistants following comprehensive technical briefings. The study was conducted from May to July 2023 in several hospitals and clinics in Surabaya that agreed to participate.

The data were analyzed using both descriptive and statistical methods. Descriptive analysis was used to show the characteristics of the sample. The Chi-Square test was applied to examine the relationship between diabetes duration, blood glucose levels, and neuropathy. A logistic regression analysis was also conducted to assess how both factors together influence the risk of neuropathy. All statistical analyses were performed using SPSS software. The significance level was considered at 0.05 for hypothesis testing. Apart from statistical analysis, the study also adhered to stringent ethical guidelines, emphasizing patient safety and autonomy. This research received ethical approval from the Health Research Ethics Committee, specifically with the approval number 08/SLE/FK/UWKS/2023. This formal approval signifies that the study protocol, including its methodology, data collection procedures, and potential risks and benefits to participants, was thoroughly reviewed and deemed ethically sound. Furthermore, a fundamental principle of ethical research, informed consent, was strictly observed. All participants provided their informed consent prior to data collection. This means that each individual was apprised of the study's processes and has right to withdraw at any time before participating.

Results

The study included 150 patients with T2D which is most of the patients were female (60%), and the largest age group was 50–59 years old (40%). Regarding diabetes duration, 45% of the patients had been living with diabetes for 5–10 years, while 33% had the disease for more than 10 years. Blood glucose levels were also a concern, with 50% of the patients having HbA1c levels greater than 10%, indicating poor blood glucose control. Additionally, 65% of the patients had diabetic neuropathy, showing that this complication is very common in the study population **(Table 1)**. Another table shows a strong connection between how long a person has diabetes and their risk of neuropathy ($p<0.05$). Among patients who had diabetes for more than 10 years, 90% had diabetic neuropathy. In comparison, only 40% of patients with diabetes for less than 5 years had neuropathy. This means that the longer a person has diabetes, the higher their risk of developing neuropathy. Over time, high blood glucose can damage the nerves that leading to this condition **(Table 2)**.

Table 1. Participants' profile.

Category	Frequency (n)	Percentage (%)
Age		
< 40 Years	25	16.07
40–60 Years	75	50.00
> 60 Years	50	33.03
Sex		
Male	60	40.00
Female	90	60.00
Duration of diabetes		
< 5 Years	40	26.07
5–10 Years	60	40.00
> 10 Years	50	33.03
HbA1c		
< 7%	55	36.07
7–10%	65	43.03
> 10%	30	20.00

The study also found a significant relationship between blood glucose levels (HbA1c) and neuropathy ($p<0.05$). Patients with HbA1c levels greater than 10% had the highest rate of neuropathy (85%), while only 30% of those with controlled blood glucose (HbA1c <7%) had neuropathy. These results confirm that poor blood glucose control greatly increases the risk of nerve damage in diabetes patients. Keeping blood glucose levels within a healthy range can help

reduce the chances of developing neuropathy **(Table 3)**. A logistic regression analysis was conducted to see which factors had the strongest impact on neuropathy risk. The results show that patients with diabetes for more than 10 years were 5.8 times more likely to develop neuropathy compared to those with diabetes for less than 5 years ($p<0.001$). Similarly, patients with very high blood glucose levels (HbA1c >10%) had 7.1 times higher odds of having neuropathy compared to those with well-controlled blood glucose ($p<0.001$). Older age also increased the risk, and women had a higher chance of developing neuropathy than men. The results of this study clearly show that both diabetes duration and high blood glucose levels strongly increase the risk of diabetic neuropathy. Patients who have had diabetes for a long time and those with poorly controlled blood glucose are at the greatest risk **(Table 4)**. These findings highlight the importance of regular blood glucose monitoring, early screening for neuropathy, and proper diabetes management to prevent complications. Improving patient awareness and healthcare strategies can help reduce the burden of diabetic neuropathy in Surabaya.

Table 2. Relationship between duration of diabetes and neuropathy.

Duration of Disease	Neuropathy	No Neuropathy	Frequency (n)	Percentage (%)
< 5 Years	Yes	5	35	70
	No	35	5	30
5–10 Years	Yes	10	50	60
	No	50	10	40
> 10 Years	Yes	25	25	100
	No	25	0	0
Test	**Value**	**df**	**Asymp. Sig. (2-sided)**	
Pearson Chi-Square	25.843	2	0.000	

Table 3. Relationship between HbA1c and neuropathy.

HbA1c	Neuropathy	No Neuropathy	Frequency (n)	Percentage (%)
< 7%	Yes	10	45	22.02
	No	45	10	77.08
7–10%	Yes	20	50	40
	No	45	20	60
> 10%	Yes	25	5	83.03
	No	5	25	16.07
Test	**Value**	**df**	**Asymp. Sig. (2-sided)**	
Pearson Chi-Square	28.192	2	0.000	

Table 4. Multivariate analysis.

Variables	Adjusted Odd Ratio (95% CI)	p
Duration of diabetes		
5–10 years vs. <5 years	2.5 (1.3–4.8)	0.005
>10 years vs. <5 years	5.8 (2.9–11.5)	<0.001
HbA1c		
7–10% vs. <7%	3.2 (1.6–6.3)	0.002
>10% vs. <7%	7.1 (3.4–14.8)	<0.001
Age	1.1 (1.02–1.2)	0.015
Female (vs. Male)	1.8 (1.1–3.0)	0.028

Discussion

This study showed a strong link between these factors and the occurrence of neuropathy. The study also found that patients who had diabetes for more than 10 years were much more likely to develop neuropathy than those with a shorter disease duration. A study supported that as diabetes progresses, the risk of neuropathy increases due to long-term exposure to high blood glucose (Sharma et al., 2021). Over time, high blood glucose damages nerves leading to serious

complications (Matoori, 2022). Similarly, an investigation explained that chronic hyperglycemia causes oxidative stress and inflammation which harms nerve cells (González et al., 2023). This finding also being supported by a study explained that early and long-term poor blood glucose control leads to permanent nerves damage (Natarajan, 2021). Even if blood glucose is later controlled, the damage that has already occurred cannot be easily reversed. This explains why patients with longer diabetes duration have a higher risk of neuropathy (Hicks & Selvin, 2019). From a healthcare perspective, these results highlight the importance of early intervention among patients with T2D. Doctors and healthcare providers should focus on early screening for neuropathy in newly diagnosed patients with diabetes (Carmichael et al., 2021). They should also encourage strict blood glucose control from the beginning of the disease to prevent long-term complications. If diabetes is well-managed early, the risk of developing neuropathy can be significantly reduced.

This study also found a strong link between high blood glucose levels and diabetic neuropathy. Patients with HbA1c levels above 10% had a much higher risk of neuropathy compared to those with well-controlled blood glucose. This confirms previous research showed that high blood glucose can cause serious damage to the nerves and make neuropathy worse over time (Chavda et al., 2024). There are several reasons why high blood glucose leads to neuropathy. When blood glucose stays high for a long time, it causes the buildup of harmful substances called advanced glycation end products (AGEs). These substances damage nerves and reduce blood flow to them that making it harder for nerves to function properly (Pal & Bhadada, 2023). Another process that worsens nerve damage is oxidative stress and the activation of the polyol pathway, which happens when glucose builds up in nerve cells and creates toxic effects (Edwards et al., 2008). The best way to prevent diabetic neuropathy is to keep blood glucose under control. A study show that tight blood glucose control can reduce the risk of neuropathy by up to 60% in diabetes patients (Wiffen, 2012). To achieve this, patients should be encouraged to follow a healthy diet, exercise regularly, and monitor their blood glucose levels. In addition, medications should be carefully managed to keep blood glucose stable. Healthcare providers should focus on educating patients about the dangers of high blood glucose and how to prevent complications.

The findings of this study are similar to those from international research but also provide unique insights into the Indonesian healthcare context. A study found that longer diabetes duration and poor blood glucose control were key risk factors for diabetic neuropathy (Braffett et al., 2020). They explained that high blood glucose over many years damages nerves and small blood vessels, making neuropathy more likely. Similarly, research emphasized that early detection and good blood glucose control can help prevent neuropathy from getting worse (Zhu et al., 2024). However, the prevalence of neuropathy in this study is higher than what has been reported in developed countries. This could be because of differences in healthcare access, awareness, and treatment adherence. In wealthier nations, diabetes management programs are more structured, helping patients control their blood glucose better and reduce complications (Marinho et al., 2017). A study in Saudi Arabia showed that neuropathy cases were lower among patients who had access to proper healthcare and regular blood glucose monitoring (Sendi et al., 2020). In contrast, in Indonesia, many diabetes patients struggle to receive regular medical check-ups, lack education about blood glucose control, and are diagnosed too late (Sofyan et al., 2023). This leads to higher neuropathy rates compared to other countries. In Southeast Asia, a study found that neuropathy prevalence in China was slightly lower than in Indonesia (Wang et al., 2023). This was likely due to government-backed diabetes management programs which help patients manage their condition more effectively. In Malaysia, a study reported that community health programs played a key role in reducing the number of neuropathy cases that showing the importance of strong healthcare initiatives (Lee et al., 2022). A study in India reported neuropathy rates similar to Indonesia (Silas et al., 2024). Both countries face challenges in healthcare services, such as late diagnosis and limited access to diabetes specialists. These healthcare limitations contribute to the high rates of diabetes complications in both nations. Even within Indonesia, there are differences in neuropathy rates between urban and rural areas. A study found that rural areas had more cases of neuropathy compared to cities (Banik & Mondal, 2019). This is because healthcare facilities are fewer in rural regions that making it harder for people to get proper treatment. This highlights the urgent need for healthcare improvements especially in rural communities.

Notwithstanding the variations in prevalence rates, this study confirms that controlling blood glucose levels is the most important factor in preventing neuropathy. Previous research emphasized that poor blood glucose control was the main reason why neuropathy developed in diabetes patients (Ang et al., 2014). Their study supports the findings of this research which showed that patients with HbA1c levels above 10% had a much higher risk of neuropathy. The results also align with a concept explains that if a patient has high blood glucose for many years, the nerve damage may continue even if blood glucose is later controlled (Thomas, 2014). This could explain why patients with diabetes for more than 10 years in this study had a much higher risk of neuropathy. These comparisons show that good diabetes management, early screening, and proper healthcare programs are critical in reducing neuropathy cases. Countries with better healthcare

systems have lower neuropathy rates. Vice versa, those with limited access to healthcare services struggle with higher complications. This study emphasizes the importance of improving diabetes care and education in Indonesia to help patients prevent neuropathy and live healthier lives. The findings of this study highlight the urgent need for better diabetes management to reduce the risk of diabetic neuropathy. Early screening programs should be a priority, especially for patients who have had diabetes for a long time or have high blood glucose levels.

Detecting neuropathy early allows for faster treatment and better prevention of severe complications (Lehmann et al., 2020). To improve care, healthcare providers need to work together, including doctors, diabetes specialists, nutritionists, nurses, and diabetes educators, to give patients complete and effective treatment (Andersen et al., 2023). One of the most important aspects of diabetes management is patient education (AlHaqwi et al., 2023). People with diabetes need to understand how their lifestyle choices affect their health. Study show that educating patients about diabetes and how to manage it can greatly improve blood glucose control and lower the risk of complications (Windrum et al., 2016). Healthcare providers should use education programs that fit the culture and daily lives of patients, so they can easily follow recommendations and manage their condition better. Another key improvement in diabetes care is the use of modern technology (Klonoff et al., 2023). Tools like Continuous Glucose Monitoring (CGM) and telemedicine services help patients track their blood glucose levels in real time. These technologies allow doctors to monitor patients remotely and make faster adjustments to treatment plans. A study found that patients who used CGM had better blood glucose control and fewer diabetes-related complications (Reaven et al., 2023). This shows that advanced technology can play a big role in managing diabetes. Overall, this study emphasizes the importance of early detection, better education, and modern technology in preventing diabetic neuropathy. Healthcare systems should focus on making these improvements widely available, especially in countries where diabetes complications are common.

This study provides important insights into the link between diabetes duration, blood glucose levels, and diabetic neuropathy in patients with T2D in Indonesia. However, a recommendation present that the large sample size and the use of standardized diagnostic methods will make the findings more reliable and accurate. This study also has some limitations. For instance, since it used a cross-sectional design, it only captured data at one point in time that meaning it cannot prove cause and effect relationships. Though the study shows that longer diabetes duration and high blood glucose levels are linked to neuropathy, it cannot confirm whether one directly causes the other. Additionally, the study did not fully account for other factors that might affect neuropathy risk, such as other comorbidities or how well patients adhere to treatment. For future research, researchers should also explore other possible risk factors, such as genetics and lifestyle choices, which may play a role in neuropathy in Asia population. Another important area for future studies is understanding patients' experiences with diabetic neuropathy. Interviews and surveys could help identify the challenges patients face in managing their condition. This information would be useful for creating better educational programs and healthcare strategies to help diabetes patients deal with the further complexities.

Conclusion

This study rigorously demonstrates that both the duration of diabetes and the level of glycemic control are significant independent risk factors for the development of neuropathy within the Indonesian diabetes population. Specifically, prolonged exposure to elevated blood glucose levels, as evidenced by higher HbA1c values, and an extended duration of diabetes significantly amplify the likelihood of neuropathic complications. These findings emphasize the critical importance of early diagnosis of diabetes, sustained and stringent glycemic management throughout the disease course, and proactive screening for neuropathy to mitigate its severe consequences in this vulnerable population. Future research should focus on long-term studies to establish the causal pathways and the precise temporal relationship between glycemic fluctuations, diabetes duration, and the progression of neuropathy in Indonesian patients. Furthermore, experimental studies are necessary to assess the efficacy of educational programs, community-based screening initiatives, and lifestyle interventions in improving glycemic control and reducing the incidence and progression of diabetic neuropathy across diverse socio-economic strata in Indonesia. Investigations into genetic predispositions and environmental factors unique to the Indonesian context that might modulate the risk of neuropathy would also provide valuable insights for personalized prevention and treatment strategies.

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AI statements

The author decided against utilizing generative text AI tools at any stage throughout the composition of this article.

Author declaration

All authors contributed to reviewing the topic, analyzing the data, and preparing the manuscript for publication. They also approved the final version of this manuscript.

Availability of data and materials

All data are available from the author when requested.

Competing interests

None.

Ethical clearance

This study received ethical approval from the relevant Institutional Review Board, as described in the method section.

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Authors' perspective

Innovation points
- The study investigates two primary risk factors for neuropathy: the duration of diabetes (how long someone has had it) and glycemic control (how well their blood glucose levels are managed).
- The central outcome being examined is the risk of neuropathy that indicating that the research aims to quantify or describe the likelihood of developing this complication.
- The study is conducted within the Indonesian diabetes population that suggesting that its findings are relevant and perhaps unique to this demographic and geographical context.

Potential areas of interest
- What specific measures were used to define glycemic control and neuropathy in the Indonesian population given potential resource or cultural variations?
- How do the findings of this study translate into practical recommendations for managing diabetes and preventing neuropathy in Indonesian healthcare settings?
- To what extent can the findings from an Indonesian diabetes population be generalized to other populations or ethnic groups with different genetic predispositions, dietary habits, or healthcare access?