Research Article

The Relationship between Glycemic Control and Peripheral Neuropathy in Patients with Type 2 Diabetes Mellitus

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Abstract. People with diabetes mellitus are prone to various complications, uncontrolled blood sugar increases the risk of peripheral neuropathy. The purpose of this study is to determine the relationship between blood sugar control and peripheral neuropathy in patients with type 2 diabetes mellitus. This study employed a quantitative, non-experimental design with a correlational approach. Data were collected using monofilament examinations and a review of medical records. The study involved 104 participants recruited via purposive sampling. Subsequently, data analysis was performed using the Chi-Square test to determine statistical significance. The results of the univariate analysis mostly had characteristics of late elderly at 32,7%, housewife occcupation at 35,6%, BMI indicating overweight at 47,1%, stage 1 hypertension with systolic blood pressure at 35,6%, and stage 2 hypertension with diastholic blood pressure at 31,7%. Uncontrolled blood glucose was 73%, and peripheral neuropathy was 81%. Bivariate analysis yielded a p-value of 0.001 (p < 0.05), indicating a statistically significant relationship between blood sugar control and peripheral neuropathy in patients with Type 2 Diabetes Mellitus.

Keywords: Blood Sugar Control; Chi-Square; Diabetes Mellitus; Monofilamen; Peripheral Neuropathy.

1. Background

Diabetes mellitus is still a global problem because it is one of the chronic diseases whose prevalence continues to increase every year throughout the world, including in Indonesia, which has an impact and burden on individuals who suffer from it as well as a burden on health services. (Erika F. Brutsaert, MD, 2023) . According to data from *the International Diabetes Federation* (IDF) in 2021 , the global prevalence of diabetes was recorded at 537 million people . This data is projected to continue growing to reach 700 million people by 2045. In the Indonesian context, neuropathy was identified as the most dominant microvascular complication, with a percentage of 17.6% (International Diabetes Federation, 2021) .

According to data from the 2023 *Indonesian Health Profile , there were 6,226 cases of diabetes mellitus.* (Ministry of Health, 2023) . Meanwhile, according to the 2023 *Central Java Health Profile* , diabetes mellitus cases ranked third at 9.59 percent of the proportion of new cases of non-communicable diseases. (Central Java Health Office, 2023) . Long-term , uncontrolled diabetes mellitus results in uncontrolled blood sugar levels and can lead to various long-term complications, one of the most common being peripheral neuropathy.

Peripheral neuropathy is a condition caused by damage to the peripheral nerves, which act as a bridge between the brain and spinal cord and other parts of the body . Clinically, it manifests as numbness, tingling, pain, and weakness in the extremities (hands and feet). (Hamid et al., 2021) . One of the main risk factors strongly linked to the development of peripheral neuropathy is poor blood sugar control. Research (Billa et al., 2023) shows that poor blood sugar control in DM patients is associated with a higher risk of developing diabetic peripheral neuropathy.

Preliminary data collected from the Medical Records Installation of Sultan Agung Islamic Hospital Semarang shows 141 cases of patients with Type 2 Diabetes Mellitus. This data was recorded over a six-month period, from January to June 2025. In addition, 62 cases of diabetic neuropathy were found in the same year. Medical record analysis shows that patients with Type 2 DM and diabetic neuropathy have poor blood sugar control profiles. These findings indicate that poor glycemic control contributes significantly to the incidence of diabetic neuropathy.

Although complications of peripheral neuropathy are common, many patients remain unaware of the symptoms because they often appear slowly and are not noticeable in the early stages. Many healthcare facilities still do not routinely perform early detection of peripheral neuropathy . This leads to blood sugar control being assessed primarily based on fasting blood sugar. (PERKENI, 2021) . This research is crucial because peripheral neuropathy impacts patients' quality of life . This study differs from others in that it uses a *monofilament test* directly on the patient to determine whether the patient has peripheral neuropathy, resulting in more accurate results.

2. Theoretical Study

Understanding Diabetes Mellitus

From a clinical perspective, Diabetes Mellitus (DM) is classified as a chronic metabolic disorder characterized by hyperglycemia (high blood sugar levels). This pathological condition arises from abnormalities in insulin secretion, insulin effectiveness, or a combination of both factors. The body's failure to regulate blood sugar has the potential to lead to serious complications. Long-term (chronic) exposure to high blood sugar levels will cause damage and failure of various organs, particularly the integrity of the nervous and vascular systems (Lestari et al., 2021) . Specifically, in patients with type 2 diabetes , the combination of impaired insulin secretion and insulin resistance in peripheral tissues leads to a complex metabolic imbalance. Given the vital role of insulin in glucose regulation, dysfunction in the pathways of insulin synthesis, release, and response is a primary trigger for this metabolic disorder. (Galicia-garcia et al., 2020) .

There are two main groups of risk factors for diabetes mellitus: modifiable (lifestyle-related) risk factors and non-modifiable (biological/genetic) risk factors. Modifiable factors include hypertension (blood pressure > 140/90 mmHg), obesity (BMI ≥ 23 kg/m²), dyslipidemia (HDL < 35 mg/dL and/or triglycerides > 250 mg/dL), physical inactivity, and poor nutritional *intake* (low fiber and high glucose). Conversely, non-modifiable risk factors include biological determinants such as gender, age, and race or ethnicity. Other risk factors are related to health and genetic track records, namely the presence of genetic predisposition factors (family history of diabetes), as well as an obstetric history of giving birth to a macrosomic baby (birth weight > 4,000 grams), a history of microsomia (birth weight < 2,500 grams), or a history of diabetes that has been experienced previously (Galicia-garcia et al., 2020) .

Understanding Blood Sugar Levels

Blood sugar levels are defined as the concentration of glucose in the bloodstream, derived from the metabolism of dietary carbohydrates and glycogen stores in the liver and skeletal muscles. Glucose regulation is heavily influenced by the hormone insulin. (Rosares & Boy, 2022) . According to the 2011 ADA *(American Diabetes Association), blood glucose examination parameters include: random blood glucose (GDS), fasting blood glucose (FBS), 2-hour postprandial blood glucose (2-hour postprandial blood glucose), and HbA1c.* Kovatchev, B, Fabris, (2020) setting blood sugar control standards that are close to normal include: pre-meal concentration between 70–120 mg/dL, post-meal concentration <180 mg/dL, weekly measurement results at 03.00 am >65 mg/dL, and monthly HbA1c levels in the range of 6.05% .

Understanding Diabetic Peripheral Neuropathy

neuropathy is the presence of signs or symptoms of peripheral nerve damage in diabetes mellitus sufferers due to chronic hyperglycemia after experiencing several causes such as metabolic , hereditary, traumatic, nutritional, neoplastic, compressive, infectious, and other secondary systemic diseases. (Laode et al., 2022) . Many people are unaware that they have the disease because a lack of vitamin B and taking many medications (polymedication) are other high-risk factors besides diabetes that can cause peripheral nerve damage. (Guyanto, 2024) . Symptoms of peripheral neuropathy This includes numbness and tingling, especially in the hands and feet .

People with peripheral neuropathy usually don't feel any temperature changes in the affected area. (Pamungkas & Usman, 2021) .

The assessment used to assess the incidence of peripheral diabetic neuropathy is by using a physical examination with 10 g *Semmes Weintein Monofilament Examination* (SWME) which is used as a simple screening method because the test is inexpensive, easy to use to assess loss of protective sensation to detect peripheral neuropathy. (Dube et al., 2022) . Before performing the examination, the instrument to be used is demonstrated and applied to the patient's hand first with their eyes open so that the patient's anxiety and fear of painful punctures are eliminated and the sensation of the monofilament is understood .

The examination is performed using a monofilament with the patient lying supine with their eyes closed. The patient is then asked to answer "yes" or "no" each time they feel pressure. The monofilament is held upright until it is bent for 2 seconds . placed at 10 different locations on each foot, namely the first, third, and fifth toes on the plantar surface, then the first, third, and fifth metatarsal heads on the plantar surface, then the middle of the plantar medially and laterally, and the plantar heel and the first distal intersessional space dorsally , and each point was tested three times. A location was declared negative if 2 responses were incorrect, and a positive sensory loss if 4 locations per foot were not detected (Shrestha et al., 2021) .

3. Research Methods

This study is a quantitative correlational study with a *cross-sectional approach* . The study sample includes all outpatients with Type 2 DM at Sultan Agung Islamic Hospital Semarang in 2025. The data collection process was carried out from August to September 2025. The sample determination was carried out using a *purposive sampling technique* , resulting in a total of 104 respondents. The instruments used included a questionnaire on respondent characteristics, a monofilament test, and secondary data from medical records.

The analysis included univariate and bivariate analyses. Data were analyzed univariately to describe the demographic characteristics of the respondents, followed by bivariate analysis using the *chi-square test* . This statistical test aims to identify the relationship between blood sugar control and peripheral neuropathy with a 95% confidence level ($\alpha = 0.05$). Results were considered significant *if* the p-value was <0.05.

4. Results And Discussion

Results

Univariate Analysis Results

Table 1 Frequency Distribution of Respondent Characteristics According to Age, Gender, Occupation, BMI, and Blood Pressure.

Characteristics	Frequency (f)	Presentation
Age		
Early Adulthood (26 - 35)	7	6.7%
Late Adulthood (36 - 45)	9	8.7
Early Elderly (46 - 55)	22	21.2%
Late Elderly (56 - 64)	34	32.7%
Seniors (>64)	32	30.8%
Gender		
Woman	63	60.6%
Man	41	39.4%
Work		
PPPK	5	4.8%
Self-employed	31	29.8%
housewife	37	35.6%
Trader	2	1.9%
Pension	8	7.7%
Doesn't work	21	20.2%
Body Mass Index		
Low Body Weight	6	5.8%
Ideal	7	6.7%
Overweight	49	47.1%

Obesity	42	40.4%
Systolic Blood Pressure		
Normal (<120)	6	5.8%
Pre-Hypertension (120-139)	31	29.8%
Stage 1 Hypertension (140-159)	37	35.6%
	24	23.1%
Stage 2 Hypertension (≥160)	6	5.8%
Hypertensive Crisis (>180)		
Diastolic Blood Pressure		
Normal (<80)	18	17.3%
Pre-Hypertension (80-90)	22	21.2%
Hypertension Stage 1 (90-99)	30	28.8%
Hypertension Grade 2 ((≥100)	33	31.7%
Hypertensive Crisis (>120)	1	1.0%

Table 1 shows the frequency distribution of respondent characteristics. The majority of respondents were female (60.6%) and in the late elderly age range (32.7%), with their primary occupation as housewives (35.6%). Regarding health indicators, respondents were predominantly overweight (47.1%). Furthermore, the distribution of blood pressure showed the highest prevalence of stage 1 hypertension for systolic (35.6%) and stage 2 hypertension for diastolic (31.7%).

Table 2 Frequency Distribution of Respondents Based on Blood Sugar Control and Peripheral Neuropathy.

Variables	Frequency (f)	Presents
Fasting Blood Sugar		
Not controlled	76	73.1%
Controlled	28	26.9%
Peripheral Neuropathy		
Not occur	20	19.2%
Happen	84	80.8%

In table 2 above, it can be concluded that the respondents with the most uncontrolled fasting glucose control were 76 respondents (73.1%), while the most experienced peripheral neuropathy were 84 respondents (80.8%).

Bivariate Analysis Results

Table 3 Chi-Square Test Results of Fasting Blood Sugar with Peripheral Neuropathy Incidence.

Peripheral Neuropathy Fasting Blood Sugar	Not occur		Happen		Total		OR	*p-value*
	n	(%)	n	(%)	n	(%)		
Tercontrol	12	42.9	16	57.1	28	100		
Uncontrolled	8	10.5	68	89.5	76	100		
							6,375	0.001
Total	20	19.2	84	80.8	104	100		

the chi-square statistical test between fasting glucose control and the incidence of peripheral neuropathy produced a *p-value* of 0.001 ($p < 0.05$). This result indicates a statistically significant relationship between the two variables in patients with Type 2 DM. Furthermore, an Odds Ratio (OR) value of 6.375 was obtained. This figure indicates that patients with uncontrolled blood sugar have a 6.375 times greater risk of developing peripheral neuropathy compared to patients with controlled blood sugar.

Discussion

Age

The results of the study showed that the characteristics of the respondents were dominated by the late elderly age group (range 56–64 years), with a proportion of 32.7%. Physiologically, increasing age is positively correlated with decreased organ function, including the nervous system and glucose metabolism, which has implications for an increased risk of peripheral neuropathy. Research conducted by Luawo et al., (2025) can support this finding, the study explained that the highest prevalence of peripheral neuropathy is in the late elderly group (56–64 years) and the elderly (>64 years). This is supported by the explanation Tubalawony &

Parinussa, (2023) which states that the aging process has an impact on reducing the capacity of pancreatic beta cells to produce insulin, thus triggering glucose intolerance.

Increasing age significantly increases the risk of complications due to progressive neurodegeneration, particularly in the 51–60 year age range (Lisa et al., 2025) . These results are supported by studies (Qalby, 2022) which also confirms the correlation between age factors and the incidence of peripheral neuropathy. which has an OR value of 102.89 (95% CI OR= 3.298-321.011) which means that those aged 50-60 years are at 102.89 times higher risk of suffering from peripheral neuropathy compared to those aged 40-49 years . In the study (Suharni et al., 2022) , it was found that the highest prevalence of neuropathy in Type 2 DM patients occurred in the 56-65 year age category.

Gender

The dominance of female respondents (60.6%) in this study is in line with the metabolic risk theory. According to (Hikmah et al., 2023) Women are known to have a greater susceptibility to Type 2 DM due to hormonal factors influenced by increased BMI, premenstrual syndrome, and menopause. These phases cause body fat accumulation that disrupts hormonal balance. Furthermore, (Purwanti et al., 2023) explained that the decrease in post-menopausal estrogen levels contributes to increased blood sugar levels, while in men, the hormone testosterone plays a role in reducing susceptibility to DM .

This research is supported by research (Lisa et al., 2025) which stated that the majority of patients in the sample were female (67.4%), due to changes in estrogen hormones after menopause . A study by Aktifah et al., 2023, also found that the majority of respondents were female (83.7%). This makes gender another risk factor for peripheral neuropathy, as women tend to be less active than men .

Work

Judging from the characteristics of the work, the results of the study shows that the majority of respondents are housewives, namely 37 people (35.6%). The data supported by the study of Hikmah et al., (2023) which also noted that the largest proportion of respondents were housewives (52.7%). The type of employment is an important factor because it is closely related to a person's daily physical activity patterns, which influence glycemic control. This is reinforced by Prabowo & Deram (2025) , who stated that physical activity can optimize insulin sensitivity and directly lower blood glucose concentrations, as well as improve nerve sensitivity in the extremities (hands and feet).

Body Mass Index (BMI)

The data analysis results showed that the majority of respondents had a Body Mass Index (BMI) in the overweight category, namely 49 people (47.1%). This high BMI has significant clinical relevance to the incidence of neuropathy. Based on the study, (Astuti et al., 2023) It was found that respondents with an overweight BMI were more likely to develop peripheral neuropathy than those with a normal weight. Excess weight can lead to excess fat storage, which forms chemical compounds called triacylglycerols in adipose cells, which can lead to the production of free fatty acids that can enter the vasculature and cause oxidative stress .

In line with the findings (Hikmah et al., 2023) The high prevalence of excess weight (53.6%) in respondents was caused by energy imbalance, namely high carbohydrate and fat intake accompanied by decreased physical activity . This sedentary lifestyle factor or lack of physical activity was also highlighted by (Priyantini et al., 2022) as the main cause of high BMI (35.6%), which pathophysiologically can trigger atherosclerosis. The accumulation of these metabolic factors explains the findings. (Aktifah et al., 2022) conclude that there is a significant positive relationship between increasing BMI values and the incidence and development of diabetic neuropathy.

Blood pressure

Based on blood pressure parameters, the study results showed that the majority of respondents were in the stage 1 hypertension group with systolic pressure (140–159 mmHg) (37 people) (35.6%), and stage 2 hypertension with diastolic pressure (≥100 mmHg) (33 people) (31.7%). Hypertension is a crucial risk factor in the pathogenesis of neuropathy. This is confirmed by the findings (Suharni et al., 2022) reported that 51.9% of diabetic patients with neuropathy had comorbid hypertension. Physiologically, hypertension causes thickening of the arterial walls, which narrows the blood vessel lumen. This condition inhibits metabolic transport in the circulation, ultimately destabilizing blood sugar regulation.

This finding is in line with the study (Hasyim et al., 2023) which confirmed a significantly higher incidence of diabetic neuropathy in patients with a history of hypertension (86.7%) compared to patients without a history of hypertension (13.3%). Statistical analysis yielded a *p*-

value of 0.001, indicating a significant association between a history of hypertension and the incidence of diabetic neuropathy. Furthermore, the distribution of hypertension severity showed the highest proportion in the grade 2 hypertension category (39.5%). This confirms the statement (Lisa et al., 2025). that hypertension is a major comorbidity experienced by more than 50% of the population of diabetes mellitus sufferers.

Blood Sugar Control

The study results showed that the majority of respondents, 76 people (73%), had uncontrolled blood glucose levels. Chronic (prolonged) hyperglycemia has the potential to destroy various body tissues, particularly nerve tissue, which is the primary cause of peripheral neuropathy. (Putri et al., 2022) . (Preston et al., 2023) explains that this nerve damage manifests itself in impaired sensory and motor function in patients. Although diabetes mellitus is a chronic disease that cannot be completely cured, the condition can be managed effectively . Increased blood sugar levels In patients with diabetes mellitus, it cannot be cured immediately, but it can be controlled with blood sugar management which includes regular consumption of medication, adequate physical activity, and adherence to the 3J diet principles (Amount, Type, and Schedule). in a diabetic diet pattern (Devi et al., 2024) .

Neuropathy Peripheral

The results of the study showed a high incidence of nerve complications, where the majority of respondents (84 people or 81%) were diagnosed with peripheral neuropathy. Billa et al., (2023) defined diabetic peripheral neuropathy as a common complication of diabetes that affects the sensory nerves in the extremities. This condition is characterized by clinical symptoms such as persistent and difficult-to-resolve paresthesias (tingling) in the feet . These findings are supported by by a study which stated that the majority experienced diabetic neuropathy, as many as 74 respondents (74%) (Widianti et al., 2024) . Another study also found that the majority of respondents experienced diabetic neuropathy, as many as 76 respondents (82.6%) out of a total of 92 respondents. (Lisa et al., 2025) . According to (Labib Bima et al., 2023) Neuropathy can occur due to damage to the microvasculature with risk factors such as long-term diabetes mellitus, excess body weight, and so on .

The Relationship Between Fasting Blood Sugar Control and the Incidence of Peripheral Neuropathy

Analysis using *the shi-square test* confirmed a statistically significant correlation between fasting blood glucose control and the incidence of peripheral neuropathy (*p-value* = 0.001; α < 0.05). Clinically, neuropathy manifestations were more dominant in respondents with uncontrolled blood sugar, characterized by subjective complaints of throbbing pain, numbness *,* and tingling (*paresthesia*) that exacerbation (worsening) at night. This finding is in line with studies (Billa et al., 2023) who also reported a significant association between persistent hyperglycemia and peripheral nerve damage (*p-value* = 0.000).

Research by Putri et al. (2022) on 56 respondents showed a similar pattern. In the group with poor blood sugar control, the proportion of peripheral neuropathy cases was recorded as dominant, at 24 respondents (80.0%), compared to those without neuropathy (20.0%). Statistical analysis used the *chi - square test* . demonstrated a significant relationship between blood sugar levels and the incidence of neuropathy, with a *p-value of* 0.000 (<0.05). Furthermore, an *Odds Ratio* (OR) of 22.22 was obtained. This figure indicates that Type 2 Diabetes Mellitus patients with uncontrolled blood sugar levels have a 22.22 times greater risk of developing peripheral neuropathy than those with controlled blood sugar levels.

Referring to the guidelines (PERKENI, 2021) Management of Type 2 Diabetes Mellitus is based on four fundamental pillars, namely education, Medical Nutrition Therapy (MNT), physical exercise, and pharmacological intervention. The implementation of these four pillars aims to maintain regular blood sugar control, which is crucial for early detection and prevention of complications . However, the urgency of implementing these pillars is confirmed by the negative findings in this study, where the majority of respondents with neuropathy (76 people or 73%) were identified as having poor blood sugar control.

5.   Conclusion and Suggestions

Conclusion

The results of this study found a significant relationship between blood sugar control and peripheral neuropathy in DM patients. Type 2. The longer Poor blood sugar control increases the risk of developing peripheral neuropathy .

Suggestion

Educational institutions can use it as information to prevent complications of diabetes mellitus, particularly peripheral neuropathy . Hospitals can use it to assist healthcare workers in providing education on *Diabetic Peripheral Neuropathy (DPN)*. reduce the prevalence of type 2 diabetes mellitus with complications . For the public, it can be used for those who experience diabetes mellitus with peripheral neuropathy complications or not, it is hoped that they will know and increase insight regarding blood sugar control in peripheral neuropathy. For future researchers, it can be used as a reference to further develop similar research with different variables, a larger total sample, and the instruments used can be combined between the DNS-Ina *(Diabetic Neuropathy Symptoms) questionnaire* and *the monofilament test.*

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