DOI: 10.30651/jqm.v10i02.31226

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Research Article

Association Between Diabetic Neuropathy and Fall Risk in Patients with Type 2 Diabetes Mellitus at Siti Khodijah Hospital Sepanjang

Mochamad Reza Irmansyah[1], Nurma Yuliyanasari[2], Laily Irfana[3], Bagus Aulia Mahdi[4]

1) Undergraduate students of the Faculty of Medicine, Muhammadiyah University of Surabaya, Surabaya, East Java, 60113, Indonesia
2) Department of Physiology, Faculty of Medicine, Muhammadiyah University of Surabaya, Surabaya, East Java, 60113, Indonesia
3) Department of Neurology, Faculty of Medicine, Muhammadiyah University of Surabaya, Surabaya, East Java, 60113, Indonesia
4) Department of Internal Medicine, Faculty of Medicine, Muhammadiyah University of Surabaya, Surabaya, East Java, 60113, Indonesia

ARTICLE INFO

Submitted : 24 th April 2026
Accepted : 2 nd July 2026
Published : 25 th July 2026

Keywords:

type 2 diabetes mellitus, diabetic neuropathy, fall risk, Timed Up and Go test

Correspondence:

mreza.irmansyah@gmail.com

ABSTRACT

Diabetic neuropathy has been recognized as a prevalent complication of type 2 diabetes mellitus, correlated with diminished balance function and an elevated likelihood of falls, which may be associated with substantial morbidity and reduced quality of life. The present study was undertaken to investigate the association between diabetic neuropathy and fall risk in patients with type 2 diabetes mellitus at Siti Khodijah Hospital, Sepanjang, using a cross-sectional design among 56 patients selected through purposive sampling. Diabetic neuropathy status was ascertained from medical record documentation reflecting clinical diagnoses established by internal medicine and neurology specialists, whereas fall risk was evaluated by administering the Timed Up and Go (TUG) test. Of participants with diabetic neuropathy, 26 of 35 patients (74.3%) were identified as higher fall risk, compared to 8 of 21 patients (38.1%) without diabetic neuropathy. Chi-square analysis yielded a statistically significant association between diabetic neuropathy and TUG-based fall risk classification ($p = 0.007$, $r = 0.338$), with an odds ratio of 4.694 (95% CI: 1.469–15.005). These results suggest that early detection of diabetic neuropathy and prompt initiation of preventive interventions may be warranted to reduce fall-related outcomes in this population.

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from insulin resistance and insufficient insulin secretion (Damanik & Yunir, 2021). This condition has been associated with a wide range of microvascular and macrovascular complications that adversely affect both physical and psychological well-being, thereby imposing a considerable burden on healthcare systems (Chatterjee et al., 2017). Among the microvascular complications, diabetic neuropathy (DN) represents one of the most frequently observed manifestations. DN has been correlated with disturbances in sensory and motor function, diminished gait capacity, and alterations in foot mechanics. These functional impairments have been associated with decreased proprioception, balance dysfunction, and postural instability, all of which are correlated with an elevated likelihood of falls in affected individuals (Scarton et al., 2017; Køhler et al., 2025).

Dysfunction of peripheral sensory and motor nerves in DN has been correlated with substantial alterations in gait biomechanics and postural stability. Damage to peripheral sensory nerves has been associated with impaired proprioceptive feedback, which diminishes the capacity to accurately detect foot position relative to the ground surface and contributes to increased postural sway. Concurrently, degeneration of motor nerves has been correlated with muscle weakness and atrophy, particularly in the distal lower-extremity musculature, manifesting as reduced ankle stability, decreased walking speed, and shortened step length. These combined sensorimotor deficits have been associated with substantial disruption of gait biomechanics and balance regulation, collectively contributing to an elevated risk of falls in individuals with DN (Reeves et al., 2021).

Falls have been broadly defined as unintentional events in which an individual loses postural control and makes contact with the ground or a lower surface (Strini et al., 2021). The Timed Up and Go (TUG) test has been extensively employed as an objective instrument for assessing fall risk through the measurement of functional mobility. Prior investigations have demonstrated that each 1-second increment in TUG completion time is associated with an approximately 29% increase in fall risk among individuals with diabetes mellitus (Wettasinghe, Dissanayake, Katulanda, et al., 2020). Evidence derived from prospective studies further corroborates this association. A systematic review and meta-analysis undertaken by Freire et al. (2024) revealed that the likelihood of falling among older adults with T2DM was 63% higher than in non-diabetic older adults, and this risk increased to 162% among those receiving insulin therapy. Furthermore, individuals with DM have been reported to be associated with a 15-fold greater likelihood of experiencing falls relative to healthy subjects, with postural instability and gait imbalance identified as primary contributing factors (Mustapa et al., 2016)

The prevalence of diabetes mellitus has increased substantially at the global level. The International Diabetes Federation reported that an estimated 537 million adults were living with diabetes mellitus in 2021, with projections indicating a continued upward trend in the coming decades (IDF Diabetes Atlas, 2021). Diabetic neuropathy has been documented to occur in approximately half of all individuals living with diabetes worldwide (Scarton et al., 2017). In Indonesia, the prevalence has been observed to be considerably higher, as a study undertaken by Susanti et al (2025) reported

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a prevalence rate of 76.65%, underscoring the magnitude of this public health concern. Although the association between diabetic neuropathy and fall risk has been widely acknowledged, findings across previous studies remain inconsistent. Diabetes has been reported to be correlated with a significantly elevated fall risk of up to 69% (Yang et al., 2016). Similarly, Sina et al (2019) identified a significant association between diabetic neuropathy and fall risk. In contrast, Dani Safitri et al (2025) reported no statistically significant association between these variables. Accordingly, further investigation is warranted to better clarify this association. Based on these considerations, this study was conducted to examine the association between diabetic neuropathy and fall risk among patients with type 2 diabetes mellitus at Siti Khodijah Hospital, Sepanjang. The findings are anticipated to contribute to a broader understanding of fall risk in patients with T2DM and to support the advancement of evidence-based fall prevention strategies in clinical practice. Accordingly, further investigation is warranted to better clarify this association. Based on these considerations, this study was conducted to examine the association between diabetic neuropathy and fall risk among patients with type 2 diabetes mellitus at Siti Khodijah Hospital, Sepanjang. The findings are anticipated to contribute to a broader understanding of fall risk in patients with T2DM and to support the advancement of evidence-based fall prevention strategies in clinical practice.

METHODS

Study Design

This study utilized an analytic observational design with a cross-sectional approach to examine the association between diabetic neuropathy and fall risk among patients with type 2 diabetes mellitus (T2DM).

Participants

The study population comprised patients with T2DM attending outpatient clinics at Siti Khodijah Sepanjang Hospital. Participants were recruited through purposive sampling based on predetermined inclusion and exclusion criteria. Inclusion criteria encompassed a confirmed T2DM diagnosis of at least five years duration, age of 40 years or older, and willingness to provide informed consent. Exclusion criteria included a history of alcohol consumption, Parkinson's disease, lower limb amputation, blindness, or lower extremity surgery within the preceding six months. The minimum sample size was determined using the correlational analytic formula for nominal-nominal variables, which requires a minimum of 50 participants with an assumed correlation coefficient (r) of 0.44 (Kelly et al., 2016).

Variables and Measurement

Diabetic neuropathy status served as the independent variable in the present study. This variable was ascertained from diagnostic documentation contained within patients' medical records, reflecting clinical assessments undertaken by internal medicine specialists and neurologists at Siti Khodijah Hospital. Diagnoses were established through evaluation of neurological complaints reported by patients, including numbness, tingling, burning sensations, and pain in the extremities, in conjunction with the Michigan Neuropathy Screening Instrument (MNSI). Fall risk constituted the dependent variable and was objectively measured utilizing the Timed Up and Go (TUG) test. Participants who completed the test in 12 seconds or more were categorized as having higher fall risk, whereas those who completed it in under 12 seconds were classified as having lower fall risk (Batool, 2019; Centers for Disease Control and Prevention, 2017).

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Data Analysis

Statistical analyses were carried out utilizing SPSS version 27. The association between diabetic neuropathy and fall risk was assessed using the Chi-square test, with a significance threshold of $p < 0.05$. The contingency coefficient was thereafter applied to determine the magnitude of the observed association, while the odds ratio (OR), accompanied by a 95% confidence interval (CI) was computed to estimate the likelihood of fall risk occurrence among patients with diabetic neuropathy

Ethical Clearance

The conduct of this study was carried out in conformity with the ethical principles set forth in the Declaration of Helsinki. Ethical approval was obtained from the Health Research Ethics Committee of Siti Khodijah Hospital under approval number No.027/KET-KEPK/II-2025.

Result

Table 1. Characteristics of Patients with Type 2 Diabetes Mellitus

No	Characteristics		Total (%) (N=56)
1	Gender	Male	21 (37.5%)
		Female	35 (62.5%)
2	Ages	40-50 (years)	12 (21.4%)
		51-60 (years)	27 (48.2%)
		61-70 (years)	17 (30.4%)
3	Duration of DM	5-7 (years)	35 (62.5%)
		8-10 (years)	10 (17.9%)
		≥11 (years)	11 (19.6%)
4	HbA1C	<7%	19 (33.9%)
		≥7%	37 (66.1%)
5	Hypertension	Yes	32 (57.1%)
		No	24 (42.9%)
6	Dyslipidemia	Yes	10 (17.9%)
		No	46 (82.1%)
7	Smoking History	Yes	7 (12.5%)
		No	49 (87.5%)
8	Treatment	Oral Antidiabetic Drugs (OAD)	38 (67.8%)
		OAD + Insulin	18 (32.2%)

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Table 2. Patient Characteristics Based on Fall Risk

No	Characteristics		High Fall Risk n (%)	Low Fall Risk n (%)	Total
1	Gender	Male	14 (66.7)	7 (33.3%)	21(37.5%)
		Female	20 (57.1%)	15 (42.9%)	35 (62.5%)
2	Ages (years)	40-50	3 (25.0%)	9 (75.0%)	12 (21.4%)
		51-60	20 (74.1%)	7 (25.9%)	27 (48.2%)
		61-70	11 (64.7%)	6 (35.3%)	17 (30.4%)
3	Duration of DM (years)	5-7	18 (51.4%)	17 (48.6%)	35 (62.5%)
		8-10	9 (90%)	1 (10%)	10 (17.9%)
		≥11	7 (63.6%)	4 (36.4%)	11 (19.6%)
4	HbA1C	<7%	12 (63.2%)	7 (36.8%)	19 (33.9%)
		≥7%	22 (59.5%)	15 (40.5%)	37 (66.1%)
5	Hypertension	Yes	17 (70.8%)	7 (29.2%)	32 (57.1%)
		No.	17 (53.1%)	15 (46.9%)	24 (42.9%)
6	Dyslipidemia	Yes	6 (60.0%)	4 (40.0%)	10 (17.9%)
		No	28 (60.9%)	18 (39.1%%)	46 (82.1%)
7	Smoking History	Yes	3 (42.9%)	4 (57.1%)	7 (12.5%)
		No	31 (63.3%)	18 (36.7%)	49 (87.5%)
8	Treatment	OAD	21 (55.3%)	17 (44.7%)	38 (67.8%)
		OAD + Insulin	13 (72.2%)	5 (27.8%)	18 (32.2%)

Table 3. Anthropometric Profile According to Fall Risk Status

No	Anthropometric Profile	High Fall Risk n (%)	Low Fall Risk n (%)	Total
1	**BMI**			
	Underweight	3 (8.82%)	3 (13.64%)	6 (10.71%)
	Normal	11 (32.35%)	8 (36.36%)	19 (33.93%)
	Overweight	14 (41.18%)	7 (31.82%)	21 (37.5%)
	Obese	6 (17.65%)	4 (18.8%)	10 (17.86%)
2	**Mid-Upper Arm Circumference (MUAC)**			
	Normal	33 (97%)	22 (100%)	55 (98.2%)
	At Risk of Malnutrition	1 (3%)	0 (0%)	1 (1.8%)
3	**Waist Circumference**			
	Normal	7 (20.6%)	5 (22.7%)	12 (21.4%)
	Central Obesity	27 (79.4%)	17 (77.3%)	44 (78.6%)

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Table 4. Association Between Diabetic Neuropathy and Fall Risk

No	DN	High Fall Risk n (%)	Low Fall Risk n (%)	Total	p-value	Contigency coefficient	OR (95% CI)
1	+ DN	26 (46.43%)	9 (16.07%)	35 (62.5%)	0.007	0.338	4.694 (1.469-15.005)
2	– DN	8 (14.29%)	13 (23.21%)	21 (37.5%)			

The demographic and clinical characteristics of the study participants are summarized in Table 1. Female participants comprised the majority of the sample (62.5%), and the 51–60 year age group represented the largest proportion of the study population (48.2%). Most participants had a diabetes duration of 5–7 years (62.5%), and 66.1% exhibited HbA1c levels of 7% or higher, reflecting suboptimal glycemic control. Hypertension was present in 57.1% of participants, and 67.8% were receiving oral antidiabetic drugs as their primary treatment.

Table 2 demonstrates that overall, 60.71% of participants were categorized as having a higher fall risk. The highest proportion of fall risk was observed among participants with a diabetes duration of 8–10 years (90%), followed by those aged 51–60 years (74.1%) and those with hypertension (70.8%).

Table 3 shows that overweight participants demonstrated the highest proportion of high fall risk (41.18%), and central obesity was present in the majority of participants classified as having higher fall risk (79.4%).

The primary outcome of this study is presented in Table 4. Of the 56 participants, 62.5% were confirmed to have diabetic neuropathy. Among those with diabetic neuropathy, 26 of 35 patients (74.3%) were categorized as having higher fall risk, in contrast to 8 of 21 patients (38.1%) among those without diabetic neuropathy. Chi-square analysis yielded a statistically significant association between diabetic neuropathy and TUG-based fall risk classification ($p = 0.007$, $r = 0.338$), with an odds ratio of 4.694 (95% CI: 1.469–15.005), indicating that patients with diabetic neuropathy demonstrated approximately 4.7 times greater odds of being categorized as having higher fall risk in comparison to those without diabetic neuropathy.

Discussion

This study identified a statistically significant association between diabetic neuropathy and fall risk in patients with type 2 diabetes mellitus. Participants with diabetic neuropathy demonstrated greater impairment in balance and functional mobility compared to those without neuropathy, as reflected in the findings presented in Table 4. These results align with the findings of Timar et al. (2016), who reported that individuals with T2DM and peripheral neuropathy exhibited increased postural sway, reduced balance confidence, and impaired gait patterns, all of which have been associated with elevated fall risk and mobility limitations. Walking is a complex physiological process that requires coordination among the central nervous system, muscle contractions, and the integration of sensory input from the lower extremities (Alam et al., 2017). Peripheral nerves play an essential role in transmitting sensory signals related to pressure, vibration, and joint position,

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which are necessary for maintaining stability during movement. Peripheral nerves play an essential role in transmitting sensory signals related to pressure, vibration, and joint position, which are necessary for maintaining stability during movement. Peripheral nerve damage in patients with diabetic neuropathy is associated with impairment of several sensory modalities, including pain, temperature, vibration, light touch, and proprioception, with deficits typically beginning in the toes and progressing proximally in a stocking distribution (Feldman et al., 2019).

Impairment of proprioceptive feedback has been correlated with a reduced capacity to detect foot position relative to the ground, which in turn has been associated with diminished postural control and increased postural sway. Kardm et al. (2025) further noted that proprioceptive deficits in individuals with T2DM are particularly pronounced at the ankle joint, a structure critically involved in maintaining postural adjustments during both static and dynamic activities. Progressive degeneration of large-diameter myelinated fibers that transmit precise sensory information has been correlated with impaired joint position detection and reduced function of muscle spindles and cutaneous mechanoreceptors, collectively contributing to increased proprioceptive errors and greater fall susceptibility.

Motor dysfunction has been correlated with elevated fall risk among patients with diabetic neuropathy. Damage to peripheral motor nerves has been associated with diminished nerve impulse transmission to musculature, manifesting as muscle weakness and reduced ankle reflexes (Sloan et al., 2021). Progressive degeneration of motor axons, particularly those innervating distal muscle groups, such as the intrinsic foot muscles and dorsiflexors, has been correlated with neurogenic muscle atrophy, a condition characterized by decreased muscle mass and increased deposition of intermuscular adipose tissue. The accumulation of intermuscular fat has been associated with impaired muscle quality and reduced contractile efficiency, which may progressively worsen functional endurance and muscle strength. Collectively, these pathological changes have been correlated with gait abnormalities, balance impairment, and an elevated likelihood of falls in this population (Parasoglou et al., 2017).

Beyond diabetic neuropathy as the primary statistically demonstrated association with fall risk, several patient-related characteristics were observed. Among study participants, a higher proportion of high fall risk was observed in the 51–60-year age group (74.1%) and the 61–70-year age group (64.7%), representing a descriptive trend in this study sample. This pattern is consistent with the broader literature documenting that proprioceptive impairment and postural instability have been observed to worsen with advancing age in individuals with T2DM. According to Umegaki (2015), the physiological aging process is related to progressive changes in peripheral nerve structure and function, which may be correlated with reduced proprioceptive ability, decreased distal muscle strength, slower neuromuscular response, and impaired postural control in older individuals with T2DM.

Regarding diabetes duration, participants with 8–10 years of disease duration had the highest observed proportion of high fall risk (90%), compared to 51.4% in the 5–7-year group and 63.6% in the ≥ 11-year group, representing a descriptive pattern in this study population. This observation is consistent with evidence in the broader literature indicating that longer diabetes duration has been recognized as a factor correlated with progressive peripheral nerve damage related to chronic hyperglycemia, oxidative stress, and microvascular dysfunction, which may be associated with reduced sensory

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and motor function and impaired balance control (Feldman et al., 2019; Tilahun et al., 2024)

Regarding glycemic control, both participants with HbA1c <7% (63.2%) and those with HbA1c ≥7% (59.5%) showed a similarly high observed proportion of high fall risk in this study sample, suggesting that elevated fall risk was prevalent across both glycemic control categories. This descriptive pattern is noteworthy in the broader literature, where persistent hyperglycemia has been recognized as potentially associated with peripheral nerve injury via microvascular impairment and metabolic dysfunction, potentially related to impaired proprioception and balance (Kim et al., 2022). Wettasinghe, Dissanayake, Allet, et al (2020), further noted that a 1% increase in HbA1c was correlated with a 23% increase in fall risk in their study population.

A higher observed proportion of high fall risk was noted among participants receiving combined OAD and insulin therapy (72.2%) compared with those receiving OAD alone (55.3%), representing a descriptive trend in this study sample. In the broader literature, combination therapy is typically employed in patients with more advanced disease or suboptimal glycemic control, a pattern correlated with progressive neuropathy related to oxidative stress and metabolic dysfunction of peripheral nerves (Lee et al., 2017; Riandini et al., 2020). This descriptive pattern is in accordance with findings reported by Freire et al (2024) , whose systematic review and meta-analysis demonstrated that older adults with T2DM receiving insulin therapy were correlated with a substantially greater likelihood of falling relative to non-insulin users.

Overweight participants (BMI 25.0–29.9 kg/m²) showed the highest observed proportion of high fall risk across all BMI categories (41.18%), and central obesity was present in 79.4% of participants classified as high fall risk, representing the most prominent descriptive trend observed in the anthropometric profile of this study population. These two findings are noteworthy, as elevated BMI and central obesity are frequently observed together in the broader literature and have been noted to be correlated with central adiposity, which in individuals with T2DM are correlated with accelerated metabolic dysfunction that contributes to progressive peripheral nerve damage, impaired proprioception, reduced postural stability, and elevated risk of fall (Khan & Andersen, 2022; Reynolds et al., 2025). Additionally, increased central adiposity has also been associated with altered body biomechanics, particularly a forward shift of the center of gravity and increased lumbar curvature, which may impair postural stability and increase susceptibility to falls (Son, 2016).

This study presents several notable strengths. The Timed Up and Go (TUG) test was utilized as an objective and validated instrument for measuring functional mobility as a proxy for fall risk, and multiple clinical characteristics were systematically documented to yield a comprehensive descriptive profile of the study population. Nevertheless, several limitations warrant acknowledgment. This study was conducted at a single healthcare facility with a relatively small sample size, which may limit the generalizability of the findings to broader populations. The statistical analysis was restricted to Chi-square testing without multivariable adjustment for potential confounders, and consequently, the independent contribution of diabetic neuropathy to fall risk could not be fully ascertained. Fall risk was evaluated solely using the TUG test, which reflects functional mobility rather than actual fall occurrence, and data on fall incidence and fall-related injuries were unavailable. Furthermore, other fall-related cofactors were not observed in this study. Future research incorporating prospective designs, larger and more diverse samples, multivariable analysis, and comprehensive assessment of fall-related cofactors is warranted to expand upon and confirm these findings

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Conclusion

Diabetic neuropathy demonstrated a significant association with elevated fall risk, as assessed by the Timed Up and Go test, among patients with type 2 diabetes mellitus. Participants with diabetic neuropathy showed a higher proportion of high fall risk compared to those without diabetic neuropathy. Furthermore, individuals with diabetic neuropathy were found to have 4.694 times higher odds of being classified as high fall risk compared to those without diabetic neuropathy, indicating a clinically meaningful elevation in fall risk despite the association being classified as weak in magnitude based on the contingency coefficient. These findings suggest that the presence of diabetic neuropathy substantially increases the likelihood of impaired functional mobility, as reflected by TUG performance, in patients with T2DM. Early identification of diabetic neuropathy through routine clinical screening, combined with timely implementation of fall prevention strategies, is therefore recommended to mitigate fall-related morbidity and enhance functional mobility in this population.

References

Alam, U., Riley, D. R., Jugdey, R. S., Azmi, S., Rajbhandari, S., D'Août, K., & Malik, R. A. (2017). Diabetic Neuropathy and Gait: A Review. In *Diabetes Therapy* (Vol. 8, Number 6, pp. 1253–1264). Springer Healthcare. https://doi.org/10.1007/s13300-017-0295-y

Batool, S. (2019). Association between diabetic neuropathy, fall risks and balance in diabetes type 2 patients. *Rawal Medical Journal*, *45*.

Centers for Disease Control and Prevention. (2017). *Timed Up & Go (TUG)*. National Center for Injury Prevention and Control. https://www.cdc.gov/steadi/media/pdfs/STEADI-Assessment-TUG-508.pdf

Chatterjee, S., Khunti, K., & Davies, M. J. (2017). Type 2 diabetes. *The Lancet*, *389*(10085), 2239–2251. https://doi.org/10.1016/S0140-6736(17)30058-2

Damanik, J., & Yunir, E. (2021). Type 2 Diabetes Mellitus and Cognitive Impairment. In *Acta Med Indones-Indones J Intern Med* • (Vol. 53, Number 2).

Dani Safitri, E., Nurdian Asnindari, L., Murni Setiawati Program Studi Keperawatan, E., Ilmu Kesehatan, F., & Yogyakarta, A. (2025). *Hubungan neuropati diabetik perifer dengan risiko jatuh pasien diabetes tipe 2 Puskesmas Godean 1 Sleman* (Vol. 3).

Feldman, E. L., Callaghan, B. C., Pop-Busui, R., Zochodne, D. W., Wright, D. E., Bennett, D. L., Bril, V., Russell, J. W., & Viswanathan, V. (2019). Diabetic neuropathy. In *Nature Reviews Disease Primers* (Vol. 5, Number 1). Nature Publishing Group. https://doi.org/10.1038/s41572-019-0092-1

Freire, L. B., Brasil-Neto, J. P., da Silva, M. L., Miranda, M. G. C., de Mattos Cruz, L., Martins, W. R., & da Silva Paz, L. P. (2024a). Risk factors for falls in older adults with diabetes mellitus: systematic review and meta-analysis. *BMC Geriatrics*, *24*(1). https://doi.org/10.1186/s12877-024-04668-0

IDF Diabetes Atlas. (2021). IDF Diabetes Atlas 2021 _ IDF Diabetes Atlas. In *IDF official website*. https://diabetesatlas.org/atlas/tenth-edition/%0Ahttps://diabetesatlas.org/data/en/world/

Kardm, S. M., Kardm, A. S., Alanazi, Z. A., Alnakhli, H. H., Alkhamis, B. A., & Reddy, R. S. (2025). Sensorimotor dysfunction and postural instability in older adults with type 2 diabetes mellitus: the role of

QANUN MEDIKA
Jurnal Kedokteran
Fakultas Kedokteran FKUM Surabaya
http://journal.um-surabaya.ac.id/index.php/qanunmedika

proprioception and neuropathy. *Frontiers in Aging Neuroscience*, *17*. https://doi.org/10.3389/fnagi.2025.1615399

Kelly, C., Fleischer, A., Yalla, S., Grewal, G. S., Albright, R., Berns, D., Crews, R., & Najafi, B. (2016). *Fear of Falling Is Prevalent in Older Adults with Diabetes Mellitus But Is Unrelated to Level of Neuropathy*.

Khan, K. S., & Andersen, H. (2022). The Impact of Diabetic Neuropathy on Activities of Daily Living, Postural Balance and Risk of Falls - A Systematic Review. *Journal of Diabetes Science and Technology*, *16*(2), 289–294. https://doi.org/10.1177/1932296821997921

Kim, Y. J., Lee, N. Y., Lee, K. A., Park, T. S., & Jin, H. Y. (2022). Influence of Glucose Fluctuation on Peripheral Nerve Damage in Streptozotocin-Induced Diabetic Rats. *Diabetes and Metabolism Journal*, *46*(1), 117–128. https://doi.org/10.4093/DMJ.2020.0275

Lee, B.-W., Kim, J. H., Ko, S.-H., Hur, K.-Y., Kim, N.-H., Rhee, S. Y., Kim, H. J., Moon, M. K., Park, S.-O., & Choi, K. M. (2017). Insulin Therapy for Adult Patients with Type 2 Diabetes Mellitus: A Position Statement of the Korean Diabetes Association, 2017. *Diabetes Metab J*, *41*, 367–373. https://doi.org/10.4093/dmj.2017.41.5.367

Mustapa, A., Justine, M., Mohd Mustafah, N., Jamil, N., & Manaf, H. (2016). Postural Control and Gait Performance in the Diabetic Peripheral Neuropathy: A Systematic Review. In *BioMed Research International* (Vol. 2016). Hindawi Limited. https://doi.org/10.1155/2016/9305025

Parasoglou, P., Rao, S., & Slade, J. M. (2017). Declining Skeletal Muscle Function in Diabetic Peripheral Neuropathy. In *Clinical Therapeutics* (Vol. 39, Number 6, pp. 1085–1103). Excerpta Medica Inc. https://doi.org/10.1016/j.clinthera.2017.05.001

Reeves, N. D., Orlando, G., & Brown, S. J. (2021). Sensory-motor mechanisms increasing falls risk in diabetic peripheral neuropathy. In *Medicina (Lithuania)* (Vol. 57, Number 5). MDPI AG. https://doi.org/10.3390/medicina57050457

Reynolds, E. L., Russman, D., Baskozos, G., Feldman, E. L., Bennett, D. L., & Callaghan, B. C. (2025). The Association Between Detailed Obesity Measurements and Peripheral Neuropathy in Persons With Diabetes. *European Journal of Neurology*, *32*(12). https://doi.org/10.1111/ene.70447

Scarton, A., Jonkers, I., Guiotto, A., Spolaor, F., Guarneri, G., Avogaro, A., Cobelli, C., & Sawacha, Z. (2017). Comparison of lower limb muscle strength between diabetic neuropathic and healthy subjects using OpenSim. *Gait and Posture*, *58*(July), 194–200. https://doi.org/10.1016/j.gaitpost.2017.07.117

Sina, M. I., Fithrie, A., & Iqbal, K. M. (2019). *INTERNATIONAL JOURNAL OF RESEARCH SCIENCE & MANAGEMENT ASSOCIATION BETWEEN DIABETIC NEUROPATHY SYMPTOM AND DIABETIC NEUROPATHY EXAMINATION WITH BERG BALANCE SCALE IN DIABETIC NEUROPATHY PATIENTS*. *6*(5). https://doi.org/10.5281/zenodo.2673435

Sloan, G., Selvarajah, D., & Tesfaye, S. (2021). Pathogenesis, diagnosis and clinical management of diabetic sensorimotor peripheral neuropathy. In *Nature Reviews*

QANUN MEDIKA
Jurnal Kedokteran
Fakultas Kedokteran FKUM Surabaya
http://journal.um-surabaya.ac.id/index.php/qanunmedika

Endocrinology (Vol. 17, Number 7, pp. 400–420). Nature Research. https://doi.org/10.1038/s41574-021-00496-z

Son, S. M. (2016). Influence of Obesity on Postural Stability in Young Adults. *Osong Public Health and Research Perspectives*, *7*(6), 378–381. https://doi.org/10.1016/j.phrp.2016.10.001

Strini, V., Schiavolin, R., & Prendin, A. (2021). Fall risk assessment scales: A systematic literature review. In *Nursing Reports* (Vol. 11, Number 2, pp. 430–443). MDPI. https://doi.org/10.3390/nursrep11020041

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

Tilahun, E., Workina, A., Habtamu, A., Tufa, H., Abebe, F., Fikadu, A., & Atomsa, F. (2024). Survival, incidence, and predictors of diabetic neuropathy among type 2 diabetic patients in hospitals of Addis Ababa. *Frontiers in Clinical Diabetes and Healthcare*, *5*. https://doi.org/10.3389/fcdhc.2024.1386426

Timar, B., Timar, R., Gaiță, L., Oancea, C., Levai, C., & Lungeanu, D. (2016). The impact of diabetic neuropathy on balance and on the risk of falls in patients with type 2 diabetes mellitus: A cross-sectional study. *PLoS ONE*, *11*(4). https://doi.org/10.1371/journal.pone.0154654

Umegaki, H. (2015). Sarcopenia and diabetes: Hyperglycemia is a risk factor for age-associated muscle mass and functional reduction. In *Journal of Diabetes Investigation* (Vol. 6, Number 6, pp. 623–624). https://doi.org/10.1111/jdi.12365

Wettasinghe, A. H., Dissanayake, D. W., Katulanda, P., & Lord, S. R. (2020). Timed up and go performance in older people with diabetes mellitus: Association with sensorimotor, function , balance, cognition, and falls. *International Journal of Physiotherapy*, *7*(2). https://doi.org/10.15621/ijphy/2020/v7i2/655

Wettasinghe, A. H., Dissanayake, D. W. N., Allet, L., Katulanda, P., & Lord, S. R. (2020). Falls in older people with diabetes: Identification of simple screening measures and explanatory risk factors. *Primary Care Diabetes*, *14*(6), 723–728. https://doi.org/10.1016/j.pcd.2020.05.006

Yang, Y., Hu, X., Zhang, Q., & Zou, R. (2016). Diabetes mellitus and risk of falls in older adults: A systematic review and meta-analysis. In *Age and Ageing* (Vol. 45, Number 6, pp. 761–767). Oxford University Press. https://doi.org/10.1093/ageing/afw140