

Prevalence of altered vibration perception and Orthostatic Hypotension in Type II Diabetes Mellitus: A Cross-Sectional Study in a manufacturing unit

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Abstract:

Background: Type 2 Diabetes Mellitus (T2DM) is associated with a variety of vascular complications, including Diabetic Peripheral Neuropathy (DPN), which affects over 40% of patients within 10 years of diagnosis. Undiagnosed DPN can significantly diminish quality of life and increase mortality. For early prognosis, plantar Vibration Perception Threshold is considered an important indicator for Diabetic Peripheral Neuropathy.

Materials & Methods: This study included 200 patients with a diagnosis of Type 2 Diabetes Mellitus (T2DM). We collected and recorded demographic data, lifestyle risk factors, and histories of comorbidities. Random blood sugar (RBS) was measured using a glucometer. Blood pressure and heart rate were assessed in three distinct phases: a supine position, after one minute of standing, and after three minutes of standing. Vibration perception was evaluated on the plantar surface of the feet using a biothesiometer. The distribution of data was evaluated with the Kolmogorov-Smirnov normality test. Subsequently, to explore potential relationships between the duration of diabetes mellitus and two key variables—vibration perception threshold and the presence of orthostatic hypotension—Spearman's rank correlation analysis was performed.

Results: The results indicate a statistically significant positive correlation between the duration of diabetes mellitus and vibration perception threshold ($\rho = 0.236$, $p < 0.01$).

Conclusions: Our findings show that as the duration of diabetes increases, so does the vibration perception threshold, indicating a progressive decline in sensation. Additionally, we found a higher prevalence of orthostatic hypotension in patients who had diabetes for 6-10 years.

Keywords: T2DM, Diabetes, Peripheral Neuropathy, DPN, VPT, Vibration Perception, Orthostatic Hypotension

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Introduction

Diabetes Mellitus (DM), a condition recognized since approximately 1000 BCE, is characterized by consistently elevated blood sugar levels and is classified into type I and type II DM (Kelshikar et al., 2024). Numerous microvascular and

macrovascular complications are also associated with diabetes mellitus (Ashok et al., 2020). Type I diabetes is characterized by almost complete loss of insulin due to β -cell destruction, whereas type II diabetes encompasses a broad range of symptoms, including decreased insulin production and

altered fat metabolism (Kelshikar et al., 2024). Across the world, there are around 387 million people affected by diabetes, while this number in Southeast Asia (SEA) is approximately more than 70 million, and by 2036, this is expected to rise to 123 million (Taufiq Zaliran et al., 2019). In just over three decades, from 1980 to 2014, the worldwide population diagnosed with diabetes has increased significantly, from 108 million to 422 million (Taufiq Zaliran et al., 2019). Concurrently, the overall prevalence rate rose from 4.7% to 8.5% (Taufiq Zaliran et al., 2019). Currently with 77 million patients, India ranks as the second-largest diabetic population in the world, just behind China. Among Indian adults aged 20 to 79, the prevalence rate of type 2 diabetes has reached 8.8% (Kelshikar et al., 2024). In Odisha, over four million people are affected by diabetes, with a prevalence of nearly 15.4% in urban areas (Meher et al., 2020). Type II Diabetes Mellitus (T2DM) is specifically associated with microvascular issues like retinopathy, nephropathy, and neuropathy (Chen et al., 2024). The estimated prevalence of neuropathy in the general community is 20%, rising to approximately 30% among hospital patients. Notably, over 40% of individuals with any form of diabetes develop neuropathy within a decade of diagnosis. (Medakkel & Sheela, 2018). Degeneration of nerve fibers as well as structural alterations in mechanoreceptors are evidenced in DM, which eventually causes deterioration of somatosensation (Drechsel et al., 2022). DPN is characterized by a gradual loss of sensitivity in the farthest parts of the body, thereby affecting small-diameter nociceptive skin fibers. It can also affect the motor fibers, resulting in muscle weakness (Domínguez-Muñoz et al., 2020). 60% of diabetic foot issues are due to nerve damage, with another 30% being related to poor blood flow (ischemia) and 20% to infections (Medakkel & Sheela, 2018). Complications from undiagnosed DPN can worsen a person's quality of life and lead to

a higher risk of death (Medakkel & Sheela, 2018). Therefore, early detection and diagnosis of DPN is a crucial factor for a better prognosis and preventing diabetic foot ulceration (Liu et al., 2021). Nowadays, there are many screening tests present to evaluate DPN clinically, such as temperature sensation, pinprick sensation, vibration perception, pressure sensation, and ankle reflexes (Liu et al., 2021). In 1905, at the Manchester Royal Infirmary, Williamson made the initial observation that individuals with diabetes mellitus had impaired vibratory perception. Subsequent research consistently linked this finding to the early stages of diabetic neuropathy (Garrow & Boulton, 2006). Plantar Vibration Perception Threshold (VPT) is considered an important indicator for diabetic foot ulcers clinically (Drechsel et al., 2022). The sensitivity and specificity of VPT for predicting diabetic neuropathy and its associated complications range from 77.3% to 100% and 72.8% to 81%, respectively (Garrow & Boulton, 2006). Vibrotactile perception relies on Meissner's corpuscles, which are most sensitive at 30 Hz, and Pacinian corpuscles, which respond to frequencies higher than 80 Hz, especially at 250 Hz. Assessment of vibration perception thresholds (VPTs) at various frequencies, indicating impairment in specific receptor subsets and the axons that connect them (Peterson et al., 2020).

A higher prevalence of DPN was identified in the T2DM patients with CAN, compared to the patients without CAN (De Paula et al., 2024). Cardiovascular Autonomic Neuropathy (CAN) is common in people with Type 2 Diabetes Mellitus (DM) (Pafili et al., 2019), affecting about 31% to 73% of them. Each year, new cases of CAN are reported in roughly 2% of this population. (Bhuyan et al., 2019). CAN impacts both the sympathetic and parasympathetic nervous systems. Orthostatic Hypotension testing helps to identify sympathetic nervous system impairment, indicating the presence of CAN. (Pafili et al., 2019). Orthostatic hypotension (OH) is a

hemodynamic disorder characterized by a sustained drop in blood pressure due to posture changes from supine to the upright position. (Migisha et al., 2021; Xiong et al., 2024), often associated with symptoms of cerebral hypoperfusion, such as light-headedness, blurred vision, and somnolence (Xiong et al., 2024). The prevalence of OH is age-dependent, with nearly 20% in older adults and 5% in middle-aged adults (Migisha et al., 2021; Xiong et al., 2024). Patients with diabetes mellitus have having higher prevalence of developing orthostatic hypotension and have a higher risk of mortality, microvascular and macrovascular complications, and cardiovascular events (Migisha et al., 2021).

Aim: To identify the association between Type 2 Diabetes Mellitus (T2DM) with Vibration Perception Threshold (VPT) and Orthostatic Hypotension (OH).

Methodology:

Study Population: In this cross-sectional study, a total of 200 patients diagnosed with type 2 DM from a manufacturing industry in Odisha, India, were recruited as subjects. Diabetes was diagnosed according to the 1999 World Health Organization Criteria (Alberti & Zimmet, 1998). Information on demographic characteristics, lifestyle risk factors, history, and treatment of comorbidities was collected. RBS was measured using a glucometer, followed by blood pressure and heart rate in three phases (supine, one minute standing, three minutes standing) were measured. Patients diagnosed with Type-2 Diabetes Mellitus with an intact site for testing for nerve conduction studies were included in the study. Male and female subjects of three age groups [<40 years, 41-50 years, 51-60 years] were included in the study. As per the Declaration of Helsinki, Informed

consent from each participant was taken before the assessment. Patients with type-1 diabetes, cardiovascular disease, renal failure, musculoskeletal disorders, liver disease, malignant tumour, diagnosed or suspected neuropathy due to any other cause, rheumatic disease and pregnancy or breast-feeding, patients with history of smoking and patients actively taking medications for hypertension such as diuretics, calcium channel blockers, beta blockers and any other drugs that may have interfered with study results in any way were excluded from the study (Jung et al., 2021; Zhu et al., 2017). Patients with known ECG or electrolyte abnormalities, and those with acute febrile illnesses, were also excluded from the study.

Measurement of vibration perception threshold: Vibration perception was measured by a trained and experienced podiatric technician using a Biothesiometer on the following positions: great toe, first, third, fifth metatarsal, instep, and heel of the feet (Figure 1) (Ashok et al., 2020). Before starting the experiment, all the participants were requested to remove their footwear and any metal jewellery on their feet, such as rings or anklets. The biothesiometer probe, primarily positioned on the palm of the subjects, allowing them to physically sense the tactile sensation of the vibration. The probes are then applied to the test sites perpendicularly with a firm pressure and a frequency at an amplitude proportional to the applied voltage (Dash & Thakur, 2017). The intensity of the stimulus was gradually increased from null to a voltage at which vibration was first detected by the subjects while blindfolded. During recording, the voltage was increased from 0 to 50 V. The grading is: Normal ≤ 15 V, Mild - 16-19V, Moderate 20-25V, Severe > 25 V (Kelshikar et al., 2024).



Figure 1: Biothesiometer probe contact points on the planter surface of the right and left feet

Measurement of Heart Rate, BP & OH:

Heart rate of the subjects was measured from the ECG tracings according to the protocol, and BP recording was done using an aneroid sphygmomanometer (MRASPXB202402001-Mocrogene) in the upper arm. All the subjects were asked about the symptoms related to autonomic disturbances, such as light-headedness, palpitations, sweating, nausea, etc. The protocol for measuring OH included Supine BP & Standing BP measurements. After 5 minutes of rest, supine BP was recorded, and Standing BP was recorded within three minutes of assuming the upright standing position. Participants with either a > 20 mm Hg drop in systolic BP (SBP) or > 10 mm Hg drop in diastolic BP (DBP) are considered to have Orthostatic Hypotension (Migisha et al., 2021).

OH, is further classified into Neurogenic and Non-neurogenic OH. The ECG recording during the lying to standing test was used to calculate the change in heart rate (ΔHR), which is the difference between the maximal heart rate at one minute of standing and the basal heart rate (the mean of the ten beats just before standing). The difference between the supine SBP and the lowest value three minutes after active standing was used to calculate ΔSBP . The ratio of the HR change to the drop in Systolic Blood Pressure (SBP) after three minutes of standing ($\Delta HR/\Delta SBP$) is used to discriminate neurogenic and

nonneurogenic OH (D'Ippolito et al., 2024). The cutoff value of the $\Delta HR/\Delta SBP$ ratio of 0.5 (0.5 or > 0.5) bpm/mm Hg as an index for neurogenic or nonneurogenic OH.

Statistical Analysis: To ascertain the distribution of the data, the Kolmogorov-Smirnov normality test was employed. Subsequently, to explore potential relationships between the duration of diabetes mellitus and two key variables—vibration perception threshold and the presence of orthostatic hypotension—Spearman's rank correlation analysis was conducted. This non-parametric method was chosen as it does not assume a normal distribution of the data and is suitable for assessing the strength and direction of monotonic relationships between variables.

Result:

Our results indicated that, on average, individuals in age group 1 had a VPT in the range of normal to mild category, whereas group 2 exhibited a higher mean VPT of 17.11 ± 6.33 . In summary, the VPT values appear to vary across the age groups, with Group 2 showing the highest average threshold. The standard deviations indicate a moderate amount of variability within each group's VPT scores (Table 1). Across all age groups, there's a linear trend of heart rate increasing from the supine position to one minute of standing, followed by a slight stabilization or decrease at three minutes of standing. Group 2 tends to have slightly higher heart rates in the supine position,

while the magnitude of heart rate change upon standing appears somewhat variable across the groups. The standard deviations

suggest a similar level of variability in heart rate within each group and at each measurement point.

Table 1: Distribution of Physiological Variables									
VPT (Mean + SD)		15.33 ± 5.19		17.11 ± 6.33		14.87 ± 6.14			
Heart Rate	3 Standing	Min95.07 ± 14.03		93.85 ± 13.89		90.3 ± 13.98			
	1 Standing	min95.32 ± 15.17		94.09 ± 15.05		91.74 ± 15.14			
	Supine	88.7 ± 14.28		90.5 ± 13.97		87.52 ± 14.07			
DBP	3 Standing	Min85.9 ± 9.83		86.6 ± 9.81		84.44 ± 9.87			
	1 Standing	min86.55 ± 10.16		87.2 ± 10.05		84.91 ± 10.09			
	Supine	83.45 ± 9.82		85.96 ± 9.81		83.61 ± 9.79			
SBP	3 Standing	Min131.75 ± 18.10		136.25 ± 17.87		137.79 ± 17.99			
	1 Standing	min133.25 ± 18.92		138.33 ± 18.69		138.64 ± 18.83			
	Supine	132.95 ± 18.30		139.08 ± 18.48		139.11 ± 18.50			
RBS (Mean ± SD)		195.32 ± 77.89		224.74 ± 79.22		205.08 ± 79.70			
No.		40		101		59			
Age Groups		Group 1 (<40 years)		Group 2 (41-50 years)		Group 3 (51-60 years)			
Total No. of Subjects		N=200, Male= 191 Female= 09							

Table 2 presents the results of normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) for three variables: Duration of Diabetes Mellitus, Postural Hypotension, and Vibration Perception Threshold. For all

three variables, both tests yielded statistically significant results (Sig. = 0.000), indicating that the distributions of these variables significantly deviate from a normal

Table 2: Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Duration of Diabetes Mellitus	0.322	200	0.000	0.748	200	0.000
Postural Hypotension	0.498	200	0.000	0.472	200	0.000
Vibration Perception Threshold	0.298	200	0.000	0.766	200	0.000
Lilliefors significance Correction						

distribution within the sample of 200 subjects (Mishra et al., 2019). As the dataset was not normally distributed, Spearman's correlation test was performed. (Table 3) to assess the monotonic relationships between Duration of Diabetes Mellitus, Vibration Perception Threshold, and Postural Hypotension. The results indicate a statistically significant positive correlation between the Duration of Diabetes Mellitus and Vibration Perception Threshold ($\rho = 0.236$, $p < 0.01$), suggesting that as the duration of diabetes increases, the vibration perception threshold tends to increase as well. In contrast, the correlation between Vibration Perception Threshold and Postural Hypotension is very weak and not statistically significant ($\rho = 0.007$, $p = 0.927$), indicating a negligible linear relationship between these two variables in this sample. There is also a non-significant, very weak positive correlation between Duration of Diabetes Mellitus and Postural Hypotension ($\rho = 0.044$, $p = 0.539$).

In our study, 18.5% of the participants were found to have orthostatic hypotension. The prevalence of orthostatic hypotension (OH) varied among patients with their diabetes mellitus duration. Among those with DM for less than one year, 14.3% (15 out of 105 participants) were positive for OH. For individuals with DM durations between one and five years, the prevalence of OH was slightly lower at 12.3% (9 out of 73 participants). A notable increase in OH prevalence was observed in the group with DM for 6-10 years, reaching 27.8% (5 out of 18 participants). Interestingly, no participants with DM durations exceeding ten years were positive for OH (Table 4). Further sub-classification of this affected group revealed that a significant proportion, specifically 44%, were diagnosed with neurogenic orthostatic hypotension, while the remaining 56% presented with non-neurogenic forms of the condition (Figure 2).

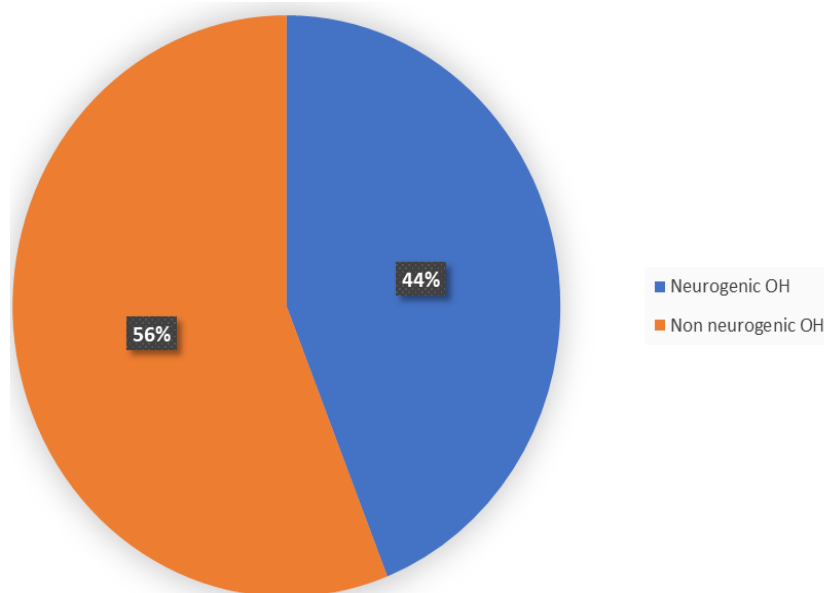


Figure 2- Distribution of Neurogenic and Non-neurogenic Orthostatic Hypotension

Table- 3 Spearman’s Correlation					
			Duration of Diabetes Mellitus	Vibration Perception Threshold	Postural Hypotension
Spearman’s Rho	Duration of Diabetes Mellitus	Correlation coefficient	1.000	0.236**	0.044
		Sig (2-tailed)		0.001	0.539
		N	200	200	200
	Vibration Perception Threshold	Correlation coefficient	0.236**	1.000	0.007
		Sig (2-tailed)	0.001		0.927
		N	200	200	200
	Postural Hypotension	Correlation coefficient	0.044	0.007	1.000
		Sig (2-tailed)	0.539	0.927	
		N	200	200	200
** Correlation is significant at the 0.01 level (2-tailed)					
Table 4: Association between Diabetes duration and Orthostatic Hypotension					
DM Duration	Numbers	OH		% of OH	
<1	105	15		14.3%	
1-5	73	9		12.3%	
6-10	18	5		27.8%	
>10	4	0		0	

Discussion:

Our study revealed a significant correlation between the vibration perception threshold and duration of diabetes mellitus. In our sample population, 26.5% of type-2 diabetic people have shown moderate to high threshold for vibration perception. The prevalence of DPN in people with type 2 diabetes varies between 6% and 51%. Other studies conducted in India have shown specific prevalence rates of 34% in Rajasthan, 31% in rural South India, and 45% in urban South India (Solanki et al., 2022). A similar study by Frykberg et al. has reported that diabetic patients with a VPT >25 V have an approximately sevenfold higher risk of ulceration (Garrow & Boulton, 2006).

The VPT test is more convenient than Nerve Conduction Study (NCS) in clinical settings because it is non-invasive, painless, and easier to perform; on the other hand,

NCS is painful, expensive, and requires specialized training to evaluate DPN (Jung et al., 2021). Studies have found that advanced age, glycemic control, and increased duration of diabetes have a significant effect on peripheral nerve function (Medakkel & Sheela, 2018). The majority of urban people are following a sedentary lifestyle, fast-food eating habits, insufficient physical activity, and have poor knowledge about diabetes management (Taufiq Zaliran et al., 2019). Moreover, the human neural system undergoes continual metabolic stress due to aging, along with declining physiological health altogether contribute to elevating the risk of DPN (Mekuria Negussie & Tilahun Bekele, 2024). On the other hand, hyperglycemia is linked with prolonged duration of DM and that activates multiple metabolic pathways, causes oxidative stress in diabetic neurons, and leads to nerve damage and neuronal ischemia (Mekuria Negussie & Tilahun

Bekele, 2024). Other complications, such as the incidence of CKD (Chronic Kidney Disease) getting significantly higher in the elevated VPT group (Zhang et al., 2024). A high vibration perception threshold (VPT) indicates a greater risk of severe retinopathy. Specifically, if the VPT exceeds 18 V, the likelihood of developing sight-threatening diabetic retinopathy is three times higher (Shen et al., 2012).

Diabetic persons with DPN had slower gait, restricted knee and ankle mobility with decreased plantar flexion, and shorter steps than healthy individuals (Dong et al., 2023). Decreased sense of vibration may also cause balance deficits and increased risk of falls. In Hafström's study it has been seen that in healthy older adults with decreased sense of vibration had negative effects on perceived and functional balance. In Bergin's study, Patients with peripheral neuropathies have shown an increased VPT (Jung et al., 2021). DPN gradually affects the peripheral sensory and motor neuronal system, which results in decreased pain sensation, loss of muscular strength, and arthropathy, leading to abnormal gait (Mustapa et al., 2016; Vinik et al., 2008).

Patients with diabetes mellitus are more prone to orthostatic hypotension and have a higher risk of mortality, along with cardiovascular complications (Kim & Farrell, 2022; Zhou et al., 2017). The prevalence of OH is described as ranging from 6-32% in people with diabetes (D'Ippolito et al., 2024). In our study population, it has been found that 18.5% of the diabetic patients were showing symptoms of Orthostatic Hypotension. Different studies in Uganda and Japan have reported a higher prevalence of abnormal postural changes in Blood Pressure (BP) among DM patients at 17% and 16% respectively (Migisha et al., 2021).

Our findings suggest a complex relationship is present between duration of diabetes mellitus (DM) and the prevalence of orthostatic hypotension (OH); we have observed that patients with a longer

duration of DM (6-10 years) had a higher prevalence of OH. However, the prevalence of OH in those with DM for 1-5 years was lower than in patients with DM for less than one year. Furthermore, no cases of OH were identified in patients who had DM for over 10 years. This absence of OH in this latter group might be attributed to the unequal distribution of patients across the groups, specifically the very small number of patients in the >10 years category. Thus, orthostatic hypotension is not solely dependent on the duration of diabetes mellitus (Bavaria et al., 2022). Population-based studies on different age groups have found that OH is associated with a higher risk of dementia. Individuals with both T2DM and OH had transient, posture-mediated cognitive deficits than diabetic individuals without OH (Xiong et al., 2024).

Our results indicated that 44% of the hypotensive patients fell under the criteria of neurogenic orthostatic hypotension. In neurogenic OH, the change in heart rate is markedly reduced or absent, whereas in non-neurogenic OH, the compensatory heart rate is maintained (Kim & Farrell, 2022). There are many complications associated with neurogenic OH, such as systemic autonomic failure, Urinary dysfunction, and gastrointestinal dysfunction. Due to redistribution of blood volume to the splanchnic circulation, postprandial hypotension is also common in neurogenic OH (Kim & Farrell, 2022).

Conclusion:

Our study conclusively demonstrates a positive correlation between diabetes duration and vibration perception threshold (VPT), indicating that an increase in vibration perception is proportional to the duration of diabetes. This finding reinforces the understanding that prolonged exposure to hyperglycaemic conditions contributes significantly to the progression of peripheral neuropathy in diabetic patients. Although a significant correlation between vibration perception and postural

hypotension was not established, a greater occurrence of orthostatic hypotension was observed in individuals with diabetes lasting 6–10 years. Further research could explore the specific mechanisms underlying this relationship and assess the efficacy of different therapeutic strategies in preserving the sensory function of diabetic individuals, which would eventually help in early intervention and improved clinical outcomes.

Calibration of the equipment: All the instruments used in this study were calibrated as per norms.

References:

1. Alberti, K. G., & Zimmet, P. Z. (1998). Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: Diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. *Diabetic Medicine: A Journal of the British Diabetic Association*, 15(7), 539–553. [https://doi.org/10.1002/\(SICI\)1096-9136\(199807\)15:7<539::AID-DIA668>3.0.CO;2-S](https://doi.org/10.1002/(SICI)1096-9136(199807)15:7<539::AID-DIA668>3.0.CO;2-S)
2. Ashok, B. H., Karnam Anantha, S., & Janarthan, K. (2020). Plantar temperature and vibration perception in patients with diabetes: A cross-sectional study. *Biocybernetics and Biomedical Engineering*, 40(4), 1600–1610. <https://doi.org/10.1016/j.bbe.2020.10.002>
3. Bavaria, D., Rathod, A., Patel, A., & Chaudhari, J. (2022). Orthostatic Hypotension and its Relationship with HbA1c Levels in Patients with Diabetes Mellitus. *National Journal of Medical Research*, 12(03), 31–34. <https://doi.org/10.55489/njmr.12032022901>
4. Bhuyan, A., Baro, A., Sarma, D., & Choudhury, B. (2019). A study of cardiac autonomic neuropathy in patients with type 2 diabetes mellitus: A Northeast India experience. *Indian Journal of Endocrinology and Metabolism*, 23(2), 246. https://doi.org/10.4103/ijem.IJEM_336_18
5. Chen, T., Xiao, S., Chen, Z., Yang, Y., Yang, B., & Liu, N. (2024). Risk factors for peripheral artery disease and diabetic peripheral neuropathy among patients with type 2 diabetes. *Diabetes Research and Clinical Practice*, 207, 111079. <https://doi.org/10.1016/j.diabres.2023.111079>
6. Dash, S., & Thakur, A. (2017). Perception of vibration threshold is a marker of diabetic neuropathy. *National Journal of Physiology, Pharmacy and Pharmacology*, 1. <https://doi.org/10.5455/njppp.2017.7.0518326052017>
7. De Paula, A. V. L., Dykstra, G. M., Da Rocha, R. B., Magalhães, A. T., Da Silva, B. A. K., & Cardoso, V. S. (2024). The association of diabetic peripheral neuropathy with cardiac autonomic neuropathy in individuals with diabetes mellitus: A systematic review. *Journal of Diabetes and Its Complications*, 38(8), 108802. <https://doi.org/10.1016/j.jdiacomp.2024.108802>
8. D'Ippolito, I., Carlucci, M. A., D'Amato, C., Lauro, D., & Spallone, V. (2024). Determinants of Orthostatic Hypotension in Type 2 Diabetes: Is Cardiac Autonomic Neuropathy the Main Factor? *Endocrine Practice*, 30(9), 802–809. <https://doi.org/10.1016/j.eprac.2024.06.008>
9. Domínguez-Muñoz, F. J., Adsuar, J. C., Villafaina, S., García-Gordillo, M. A., Hernández-Mocholí, M. Á., Collado-Mateo, D., & Gusi, N. (2020). Test-Retest Reliability of Vibration Perception Threshold Test in People with Type 2 Diabetes Mellitus. *International Journal of Environmental Research and Public Health*, 17(5),

1773.
<https://doi.org/10.3390/ijerph17051773>
10. Dong, L., Hu, Y., Xu, L., Zeng, H., Shen, W., Esser, P., Dawes, H., & Liu, F. (2023). Abnormal vibration perception threshold alters the gait features in type 2 diabetes mellitus patients. *Frontiers in Endocrinology*, 13, 1092764. <https://doi.org/10.3389/fendo.2022.1092764>
 11. Drechsel, T. J., Zippenfennig, C., Schmidt, D., & Milani, T. L. (2022). The Effect of Subliminal Electrical Noise Stimulation on Plantar Vibration Sensitivity in Persons with Diabetes Mellitus. *Biomedicines*, 10(8), 1880. <https://doi.org/10.3390/biomedicines10081880>
 12. Garrow, A. P., & Boulton, A. J. M. (2006). Vibration perception threshold—A valuable assessment of neural dysfunction in people with diabetes. *Diabetes/Metabolism Research and Reviews*, 22(5), 411–419. <https://doi.org/10.1002/dmrr.657>
 13. Jung, J., Kim, M.-G., Kang, Y.-J., Min, K., Han, K.-A., & Choi, H. (2021). Vibration Perception Threshold and Related Factors for Balance Assessment in Patients with Type 2 Diabetes Mellitus. *International Journal of Environmental Research and Public Health*, 18(11), 6046. <https://doi.org/10.3390/ijerph18116046>
 14. Kelshikar, S., Athavale, V., Parekh, R. A., & Ranka, M. (2024). The Role of a Biothesiometer in Early Detection and Management of Diabetic Neuropathy. *Cureus*. <https://doi.org/10.7759/cureus.70588>
 15. Kim, M. J., & Farrell, J. (2022). Orthostatic Hypotension: A Practical Approach. *American Family Physician*, 105(1), 39–49.
 16. Liu, M., Gao, Y., Chen, D., Lin, S., Wang, C., Chen, L., & Ran, X. (2021). Quantitative vibration perception threshold in assessing diabetic polyneuropathy: Should the cut-off value be adjusted for Chinese individuals with type 2 diabetes? *Journal of Diabetes Investigation*, 12(9), 1663–1670. <https://doi.org/10.1111/jdi.13515>
 17. Medakkel, A. A., & Sheela, P. (2018). Vibration Perception Threshold Values and Clinical Symptoms of Diabetic Peripheral Neuropathy. *JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH*. <https://doi.org/10.7860/JCDR/2018/32825.11549>
 18. Meher, D., Kar, S., Pathak, M., & Singh, S. (2020). Quality of Life Assessment in Diabetic Patients Using a Validated Tool in a Patient Population Visiting a Tertiary Care Center in Bhubaneswar, Odisha, India. *The Scientific World Journal*, 2020, 1–7. <https://doi.org/10.1155/2020/7571838>
 19. 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>
 20. Migisha, R., Agaba, D. C., Katamba, G., Manne-Goehler, J., Muyingo, A., & Siedner, M. J. (2021). Postural changes in blood pressure among patients with diabetes attending a referral hospital in southwestern Uganda: A cross-sectional study. *BMC Cardiovascular Disorders*, 21(1), 213. <https://doi.org/10.1186/s12872-021-02022-5>
 21. Mishra, P., Pandey, C. M., Singh, U., Gupta, A., Sahu, C., & Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. *Annals of Cardiac Anaesthesia*, 22(1), 67–72. https://doi.org/10.4103/aca.ACA_157_18
 22. 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. *BioMed Research International*, 2016, 1–14.
<https://doi.org/10.1155/2016/9305025>
23. Pafili, K., Trypsianis, G., Papazoglou, D., Maltezos, E., & Papanas, N. (2019). Correlation of cardiac autonomic neuropathy with small and large peripheral nerve function in type 2 diabetes mellitus. *Diabetes Research and Clinical Practice*, 156, 107844.
<https://doi.org/10.1016/j.diabres.2019.107844>
 24. Peterson, M., Pingel, R., Rolandsson, O., & Dahlin, L. B. (2020). Vibrotactile perception on the sole of the foot in an older group of people with normal glucose tolerance and type 2 diabetes. *SAGE Open Medicine*, 8, 2050312120931640.
<https://doi.org/10.1177/2050312120931640>
 25. Shen, J., Liu, F., Zeng, H., Wang, J., Zhao, J.-G., Zhao, J., Lu, F.-D., & Jia, W.-P. (2012). Vibrating Perception Threshold and Body Mass Index Are Associated with Abnormal Foot Plantar Pressure in Type 2 Diabetes Outpatients. *Diabetes Technology & Therapeutics*, 14(11), 1053–1059.
<https://doi.org/10.1089/dia.2012.0146>
 26. Solanki, J. D., Doshi, R. D., Virani, N. R., Sheth, N. S., Dhamecha, J. K., & Shah, C. J. (2022). Prevalence and correlates of vibration perception threshold based diabetic peripheral neuropathy in Gujarati urban population: A cross sectional study. *Journal of Family Medicine and Primary Care*, 11(11), 7055–7059.
https://doi.org/10.4103/jfmpe.jfmpe_540_22
 27. Taufiq Zaliran, M., Md Rezali, K. A., Guan, N. Y., As'array, A., & Abdul Jalil, N. A. (2019). Review on the Vibration Perception Threshold to Early Detect Diabetes Mellitus. *Journal of Physics: Conference Series*, 1262(1), 012033.
<https://doi.org/10.1088/1742-6596/1262/1/012033>
 28. Vinik, A. I., Strotmeyer, E. S., Nakave, A. A., & Patel, C. V. (2008). Diabetic Neuropathy in Older Adults. *Clinics in Geriatric Medicine*, 24(3), 407–435.
<https://doi.org/10.1016/j.cger.2008.03.011>
 29. Xiong, Q., Li, F., Chi, H., Yang, Y., Li, M., Liu, Y., Zhang, Y., Leng, B., Qi, X., Sun, H., Li, Z., & Zhang, J. (2024). Orthostatic Hypotension Promotes the Progression From Mild Cognitive Impairment to Dementia in Type 2 Diabetes Mellitus. *The Journal of Clinical Endocrinology & Metabolism*, 109(6), 1454–1463.
<https://doi.org/10.1210/clinem/dgad764>
 30. Zhang, Y., Zheng, B., Li, Y., Shen, X., Huang, L., Zhao, F., & Yan, S. (2024). Association of high vibration perception threshold with reduced renal function in patients with type 2 diabetes. *Frontiers in Endocrinology*, 15, 1357294.
<https://doi.org/10.3389/fendo.2024.1357294>
 31. Zhou, Y., Ke, S.-J., Qiu, X.-P., & Liu, L.-B. (2017). Prevalence, risk factors, and prognosis of orthostatic hypotension in diabetic patients: A systematic review and meta-analysis. *Medicine*, 96(36), e8004.
<https://doi.org/10.1097/MD.00000000000008004>
 32. Zhu, X., Mao, F., Liu, S., Zheng, H., Lu, B., & Li, Y. (2017). Association of SUDOSCAN Values with Vibration Perception Threshold in Chinese Patients with Type 2 Diabetes Mellitus. *International Journal of Endocrinology*, 2017, 1–5.
<https://doi.org/10.1155/2017/8435252>