Cureus
Part of SPRINGER NATURE

Open Access Original Article

Vibration Perception in Patients With Diabetes: Exploring Great Toe and Metatarsal Thresholds

Ajay Jha [1], Abha Singh [1], Ashok Sunder [1], Deb Sanjay Nag [2], Saukat Das [1]

1. Medicine, Tata Main Hospital, Jamshedpur, IND 2. Anesthesiology, Tata Main Hospital, Jamshedpur, IND

Corresponding author: Deb Sanjay Nag, ds.nag@tatasteel.com

Review began 11/11/2026
Review ended 11/14/2026
Published 11/17/2026

© **Copyright** 2026
Jha et al. This is an open access article distributed under the terms of the Creative Commons Attribution License CC-BY 4.0., which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

DOI: 10.7759/cureus.119817

Abstract

Diabetes mellitus is a significant global health issue, with type 2 diabetes mellitus (T2DM) notably linked to peripheral neuropathy, which adversely affects patients' vibration perception. This study aimed to assess the vibration perception threshold (VPT) at the great toe and other sites of the foot in patients with T2DM attending a tertiary care hospital in Jharkhand, India. In this retrospective study, VPT records of the first 100 consecutive eligible patients with T2DM (56 men, 44 women; mean age 55.2 ± 11.8 years), measured with a biothesiometer at the great toe, first, third, and fifth metatarsal heads, midfoot, and heel of both feet, were analyzed. Based on the worse great toe VPT, 72 patients (72%) had an abnormal VPT (>15 V), and 40 (40%) were in the severe range (>25 V). VPT differed significantly across foot sites (Friedman χ^2=98.56, df=5, p<0.001) but not between the right and left feet. VPT showed a significant positive correlation with age at all 12 sites tested (Spearman ρ=0.57 to 0.67, p<0.001 for all). This study underscores the importance of early neuropathy screening in patients with diabetes, particularly older patients, to mitigate complications such as foot ulcers and limb amputations.

Categories: Internal Medicine
Keywords: biothesiometer, great toe and metatarsal, microvascular complications, peripheral neuropathy, vibration perception threshold

Introduction

Introduction

Diabetes mellitus, particularly type 2 diabetes mellitus (T2DM), affects millions worldwide and is associated with numerous microvascular and macrovascular complications that pose substantial public health challenges [1,2]. Peripheral neuropathy is one of the most prevalent microvascular complications of diabetes, significantly impacting the quality of life of affected individuals [3,4]. Studies suggest that nearly 50% of patients with diabetes may develop some form of neuropathy, highlighting the urgent need for effective assessment and management strategies [5].

Understanding peripheral neuropathy

Peripheral neuropathy in diabetes primarily results from damage to large-diameter myelinated nerve fibers essential for sensation, including vibration, touch, and proprioception. As these fibers degenerate, patients may experience reduced vibratory sensation, impairing balance and increasing the risk of falls [6]. Furthermore, loss of sensation can lead to delayed diagnoses of foot injuries or ulcers, complicating diabetes management [7].

Vibration perception threshold

The assessment of vibration perception threshold (VPT) is a crucial component of evaluating diabetic neuropathy [8]. VPT provides valuable insights into the functional status of peripheral nerves and serves as a direct measure of sensory loss in patients WITH diabetes [9]. Elevated VPT readings indicate greater losses in proprioception and balance, heightening the risk of foot injuries and complications [10].

VPT is measured with a biothesiometer, a hand-held device whose probe delivers a vibratory stimulus of fixed frequency to the skin. The amplitude of vibration is controlled by the applied voltage, displayed on the device from 0 to 50 V, and is increased gradually until the patient first perceives the vibration. The voltage at that moment is the VPT: the higher the voltage needed, the poorer the vibration perception, reflecting dysfunction of large myelinated sensory fibers [9]. VPT is a quantitative screening and risk-stratification test rather than a diagnostic test for neuropathy; a great toe VPT above 25 V identifies patients at substantially increased risk of foot ulceration [11]. Its limitations are that it depends on patient cooperation and attention, increases with age [12], assesses only large-fiber function, and cannot characterize the type or distribution of neuropathy. Nerve conduction studies remain the reference standard for confirming diabetic peripheral neuropathy [3], whereas simpler bedside tests such as the 10-g monofilament, the 128-Hz tuning fork, and the Ipswich Touch Test are used for screening [7].

How to cite this article
Jha A, Singh A, Sunder A, et al. (November 17, 2026) Vibration Perception in Patients With Diabetes: Exploring Great Toe and Metatarsal Thresholds. Cureus 18(11): e119817. DOI 10.7759/cureus.119817

Anatomical considerations

The great toe and metatarsals are particularly significant for evaluating diabetic neuropathy due to their anatomical position as the most distal parts of the lower extremities [12]. Prior studies have shown that these regions are commonly affected by neuropathy, making them ideal targets for VPT assessments [13].

Objectives of the study

The primary goal of this study was to describe VPT levels among patients with T2DM in Jharkhand, India, thereby contributing valuable data to the existing literature on diabetic neuropathy. The specific objectives were to (1) compare VPT across six anatomical sites of the foot, (2) compare VPT between the right and left feet, (3) compare VPT and VPT grades between males and females, and (4) examine the association between VPT and age. The study was descriptive and did not evaluate the effect of screening on foot ulcers or amputations.

Materials And Methods

Study design

This was a retrospective analysis of patients visiting the outpatient department of a tertiary care hospital in Jharkhand, India. Records of patients seen between January 2024 and June 2024 were screened. VPT testing had been performed as part of routine clinical care. In accordance with the policy of the Institutional Ethics Committee of Tata Main Hospital, Jamshedpur, retrospective analyses of routinely collected clinical records are exempt from ethics committee review, and the requirement for informed consent for this analysis was waived; no approval reference number or date is therefore applicable. In line with the objectives, VPT was compared across six foot sites, between the right and left feet and between sexes, and its association with age was examined.

Participants

We studied the first 100 consecutive participants diagnosed with T2DM meeting the inclusion criteria of adult patients aged 30 to 80 years with a diagnosis of T2DM for at least one year (diagnosed according to American Diabetes Association criteria [14] and documented in the medical records) (first visit only; repeat visits were not included). These 100 patients were tested between 3 January and 17 February 2024. Participants with conditions affecting peripheral sensation (such as hypothyroidism, chronic alcoholism, or vitamin deficiencies), previous foot surgery, and those on medications known to induce neuropathy were excluded from the study [3].

Data collection and quality control

Demographic data and VPT readings were exported from the electronic database of the diabetic foot clinic, into which the technician enters the readings at the time of testing. The exported data were cross-checked against the medical records by a second author for completeness and transcription errors before analysis. A reading of 0 V at a site was treated as missing (three readings, all at the great toe).

Vibration perception measurement

VPTs were assessed using a Biothesiometer (Vibrotherm-Dx; Diabetik Foot Care India Pvt. Ltd., Chennai, India), a device specifically designed to measure the minimum level of vibratory stimuli detectable by the participant (range 0 to 50 V) [12]. The device was factory-calibrated and serviced according to the manufacturer's schedule, and its self-check was performed before each testing session. Testing was performed in a quiet room with the patient lying supine and relaxed. The procedure was explained, and the vibration was first demonstrated on the patient's hand so that the sensation was familiar. With the patient's eyes closed, the probe was held perpendicular to the skin with light, constant pressure, and the voltage was increased gradually and continuously from 0 V; no fixed stimulus duration was used. The patient was asked to respond as soon as vibration was first felt, and the voltage displayed at that moment was recorded as the VPT. VPT was measured at six sites on each foot: the plantar surface of the great toe, the first, third, and fifth metatarsal heads, the midfoot (plantar center of the medial longitudinal arch) and the heel (plantar center of the heel). The mean value of three consecutive measurements at each site was calculated and recorded, ensuring reliable VPT data for each participant. Measurements were performed by trained technicians of the diabetic foot clinic, all of whom followed the same standardized protocol for every patient.

VPT classification

To facilitate interpretation of VPT results, each patient was graded using the established classification illustrated in Table *1* [15]. For each patient, the higher of the right and left great toe readings, referred to throughout as the worse great toe VPT, was used for grading. A VPT above 15 V was considered abnormal [15], and a VPT above 25 V was considered severe because this threshold identifies patients at substantially increased risk of foot ulceration [11].

Grade	Normal	Mild	Moderate	Severe
Vibration perception threshold (VPT), large-fiber function	≤15 V	16 to 20 V	21 to 25 V	>25 V

TABLE 1: Vibration perception threshold classification source

Adapted from Medakkel and Sheela [15]

Statistical analysis

Data were compiled in Microsoft Excel (Microsoft Corp., Redmond, WA, USA) and analyzed using R version 4.3.3 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables are presented as mean ± standard deviation (SD) and median (interquartile range, IQR), and categorical variables as frequency and percentage. Normality was assessed with the Shapiro-Wilk test. Because VPT values were not normally distributed at any site ($p<0.001$ for all), non-parametric tests were used. The Wilcoxon signed-rank test compared the right and left feet at each site. The Friedman test compared VPT across the six sites (mean of both feet), followed by pairwise Wilcoxon signed-rank tests of each site against the great toe, with Bonferroni correction for five comparisons. The Mann-Whitney U test compared great toe VPT between sexes, the chi-square test compared VPT grades between sexes, and the Kruskal-Wallis test compared great toe VPT across age groups. The association between age and VPT was assessed with Spearman's rank correlation coefficient (ρ), which was the primary and only correlation measure because VPT was not normally distributed; its test statistic is reported as

$$t = \rho \sqrt{\frac{n - 2}{1 - \rho^2}}$$

with $n - 2$ degrees of freedom. For the 12 site-specific correlations, significance was also judged against a Bonferroni-adjusted threshold of $p<0.0042$ (0.05/12). Readings of 50 V, the device maximum, indicate that the true VPT was 50 V or higher. These readings were retained at 50 V in the main analysis; because the analyses were rank-based, they were treated as tied highest values, and VPT grading was unaffected because all such readings fall in the severe range. To assess the influence of this ceiling, the correlation and age-group analyses were repeated after excluding readings of 50 V. A two-tailed p-value <0.05 was considered statistically significant.

Results

Demographics

Among the 100 analyzed patients, 56 were male (56%), and 44 were female (44%), with a mean age of 55.2 ± 11.8 years (median 56 years; range: 30 to 77 years). The mean age was similar in females (54.5 ± 11.0 years) and males (55.7 ± 12.4 years).

VPT at different foot sites

VPT values at each site are shown in Table *2*. No significant difference was observed between the right and left feet at any site. VPT differed significantly across the six sites (Friedman $\chi^2=98.56$, df=5, $p<0.001$). The mean VPT of both feet was 24.9 V at the great toe, 23.6 to 23.9 V at the metatarsal heads and midfoot, and 26.6 V at the heel. Great toe VPT was significantly higher than VPT at the first (Bonferroni-adjusted $p=0.001$), third ($p=0.003$), and fifth ($p=0.020$) metatarsal heads, did not differ from the midfoot ($p=0.173$), and was lower than the heel ($p=0.002$). Fourteen (14%) patients reached the device maximum of 50 V at one or both great toes, and 18 (18%) had a reading of 50 V at one or more sites. The proportion with a worse great toe VPT of 50 V increased with age: none of 33 patients aged 30 to 49 years, 4 of 28 (14%) aged 50 to 59 years, 5 of 26 (19%) aged 60 to 69 years, and 5 of 13 (38%) aged 70 to 80 years.

Site	Right: mean ± SD (V)	Right: median (IQR)	Left: mean ± SD (V)	Left: median (IQR)	Wilcoxon V (right vs left)	p-value
Great toe	24.6 ± 13.2	22 (14-31)	24.6 ± 13.8	20 (14-34)	1658	0.312
First metatarsal head	23.4 ± 13.2	19 (13-34)	23.9 ± 14.2	18 (12-31)	1546.5	0.871
Third metatarsal head	23.4 ± 13.3	18 (13-30)	23.8 ± 13.8	19 (12-31)	1437	0.606
Fifth metatarsal head	23.6 ± 13.3	21 (13-29)	24.3 ± 13.9	20 (13-33)	1216.5	0.106
Midfoot	23.9 ± 13.5	18 (14-30)	23.8 ± 13.0	20 (14-31)	1493.5	0.543
Heel	26.6 ± 13.9	24 (15-39)	26.6 ± 13.7	25 (14-36)	1268	0.883

TABLE 2: Vibration perception threshold at each foot site in the right and left feet (n=100)

Values in volts (V). Right-left comparisons were made using the Wilcoxon signed-rank test. A reading of 0 V was treated as missing (right great toe, n=98; left great toe, n=99).

IQR: interquartile range; SD: standard deviation.

VPT grading

Using the worse great toe VPT, 72 (72%) patients had an abnormal VPT, and 40 (40%) were in the severe range (Table 3). The distribution of grades did not differ significantly between females and males (χ^2=3.69, df=3, p=0.297), nor did the worse great toe VPT (median 24 V in both; Mann-Whitney U=1149.5, p=0.568).

VPT grade (worse great toe VPT)	All patients (n=100), n (%)	Females (n=44), n (%)	Males (n=56), n (%)
Normal (≤15 V)	28 (28.0)	12 (27.3)	16 (28.6)
Mild (16 to 20 V)	13 (13.0)	5 (11.4)	8 (14.3)
Moderate (21 to 25 V)	19 (19.0)	12 (27.3)	7 (12.5)
Severe (>25 V)	40 (40.0)	15 (34.1)	25 (44.6)

TABLE 3: Distribution of patients by VPT grade, overall, and by sex

Grades are defined in Table 1, based on the worse great toe VPT (the higher of the two great toe readings). Females vs males: χ^2=3.69, df=3, p=0.297.

VPT, vibration perception threshold.

Correlation analysis

Age showed a significant positive correlation with VPT at every site on both feet (Spearman ρ=0.57 to 0.67; p<0.001 for all, below the Bonferroni-adjusted threshold) (Table 4). After readings of 50 V were excluded, the correlations remained significant at every site (ρ=0.56 to 0.66; p<0.001 for all). Great toe VPT rose progressively across age groups: the median (IQR) worse great toe VPT was 15 (11-20) V in patients aged 30 to 49 years (n=33), 24 (15-30) V at 50 to 59 years (n=28), 28 (24-38) V at 60 to 69 years (n=26), and 48 (26-50) V at 70 to 80 years (n=13) (Kruskal-Wallis H=32.31, df=3, p<0.001). Severe VPT was present in 5 of 33 (15%) patients aged 30 to 49 years and in 10 of 13 (77%) aged 70 to 80 years. After ceiling readings were excluded, the median (IQR) worse great toe VPT was 15 (11-20), 23 (15-26), 25 (24-31), and 28 (22-48) V in the four age groups (n=33, 24, 21, and 8, respectively), and the difference across age groups remained significant (Kruskal-Wallis H=21.82, df=3, p<0.001).

Site	Side	n	ρ	t (df)	p-value	n, excluding 50 V	ρ, excluding 50 V	p-value, excluding 50 V
Great toe	Right	98	0.661	8.62 (96)	<0.001	87	0.626	<0.001
Great toe	Left	99	0.617	7.73 (97)	<0.001	88	0.6	<0.001
First metatarsal head	Right	100	0.603	7.48 (98)	<0.001	91	0.611	<0.001
First metatarsal head	Left	100	0.573	6.93 (98)	<0.001	88	0.555	<0.001
Third metatarsal head	Right	100	0.661	8.72 (98)	<0.001	91	0.657	<0.001
Third metatarsal head	Left	100	0.614	7.70 (98)	<0.001	90	0.625	<0.001
Fifth metatarsal head	Right	100	0.632	8.07 (98)	<0.001	92	0.608	<0.001
Fifth metatarsal head	Left	100	0.636	8.16 (98)	<0.001	88	0.613	<0.001
Midfoot	Right	100	0.671	8.95 (98)	<0.001	91	0.633	<0.001
Midfoot	Left	100	0.607	7.57 (98)	<0.001	92	0.612	<0.001
Heel	Right	100	0.62	7.82 (98)	<0.001	87	0.6	<0.001
Heel	Left	100	0.589	7.22 (98)	<0.001	88	0.566	<0.001
Worse great toe VPT	Either	100	0.623	7.88 (98)	<0.001	86	0.574	<0.001

TABLE 4: Correlation between age and vibration perception threshold at each foot site

Worse great toe VPT: the higher of the right and left great toe readings. Excluding 50 V: sensitivity analysis after removing readings at the device maximum. All p-values remain significant after Bonferroni correction for 12 comparisons (threshold p<0.0042).

ρ: Spearman's rank correlation coefficient; df: degrees of freedom; n: patients with a valid reading; t: test statistic for Spearman's ρ, $t = \rho\sqrt{[(n-2)/(1-\rho^2)]}$; VPT: vibration perception threshold.

Discussion

This study highlights the high prevalence of elevated VPTs among patients with T2DM: 72% had an abnormal worse great toe VPT, and 40% were in the severe range. A similar predominance of moderate-to-severe readings has been reported in Indian patients graded with the same biothesiometer cut-offs [15,16]. VPT correlated strongly and consistently with age at every site tested, and the median great toe VPT rose from 15 V in patients aged 30 to 49 years to 48 V in those aged 70 to 80 years; because 38% of the oldest patients reached the 50 V device maximum, this median is a minimum estimate, and the true VPT in this group may be higher. The association persisted, with similar strength, after ceiling readings were excluded. Age was also the only factor that predicted VPT in a community sample of healthy adults [12], so part of this rise reflects normal aging; nevertheless, most patients aged 60 years or older had readings in the severe range, well above normal thresholds. Previous studies indicate that longer diabetes duration is an important predictor of diabetic neuropathy [6], and both longer duration and peripheral neuropathy are established risk factors for diabetic foot ulceration [17]. Because age and diabetes duration usually rise together, part of the age effect seen here may reflect longer disease duration, which could not be assessed in this dataset. As diabetes duration and glycemic control were unavailable and no multivariable analysis was possible, the association between age and VPT should not be interpreted as independent or causal. VPT was symmetrical between the two feet, and the great toe recorded higher thresholds than the metatarsal heads, in keeping with the length-dependent pattern of diabetic neuropathy; the highest values were recorded at the heel, possibly reflecting its thicker plantar soft tissue. These findings suggest that regular assessment of VPTs could help identify patients with impaired vibration perception [16]; however, VPT is a screening rather than a diagnostic test, and peripheral neuropathy was not confirmed by nerve conduction studies in this cohort.

Clinical implications

Elevated VPT, as observed in this study, has potential clinical implications. The inability to perceive vibratory stimuli can lead to unnoticed foot injuries, escalating to ulcers and potentially resulting in limb amputations [18,19]. Enhancing awareness about foot care, including appropriate footwear, among patients with diabetes may help mitigate risks related to diabetic neuropathy [20,21]. Furthermore, implementing regular VPT assessments as part of standard diabetic care could potentially facilitate timely interventions and help prevent complications associated with peripheral neuropathy [22]. However, this study did not evaluate the effectiveness of screening, the subsequent development of foot ulcers, or amputation rates; these remain potential rather than demonstrated benefits. In developing countries, where affordability and

access shape diabetes care, a simple, low-cost bedside test such as VPT is well suited to routine follow-up [23]. A comprehensive multidisciplinary approach, including endocrinologists, podiatrists, and diabetes educators, may improve clinical outcomes for patients with T2DM [24].

Recommendations for future research

Future studies should explore therapeutic modalities capable of enhancing sensory recovery in patients with diabetes. Interventions such as physical therapy, tailored exercise programs, and sensory stimulation therapies could alleviate the effects of diabetic neuropathy [6,25]. Additionally, longitudinal studies assessing the efficacy of regular VPT evaluations in routine diabetic care protocols can bolster evidence-based practices aimed at improving the management of diabetes-related complications.

Limitations

This study has several limitations. First, it was a retrospective, single-center analysis of a relatively small sample of the first 100 consecutive eligible patients, all tested within a period of about six weeks, which may limit generalizability and precision. Second, duration of diabetes, glycemic control (HbA1c), body mass index, height, and other metabolic factors known to influence neuropathy [26] were not available, so the independent effect of disease duration could not be assessed, no multivariable analysis was possible, and the correlation with age may be confounded by these factors. Third, there was no non-diabetic control group, and age-specific normal values were not applied, so the contribution of normal aging to elevated VPT cannot be separated from that of diabetes. Fourth, the biothesiometer has an upper limit of 50 V; 14% of patients reached this ceiling at the great toe, rising to 38% of those aged 70 to 80 years. Their true VPT could not be measured, which compresses the upper range of values, makes the medians in the oldest age group minimum estimates, and may underestimate the strength of the associations with age. Severity grading was not affected because all such readings fall in the severe range, and the association with age persisted when these readings were excluded. Fifth, VPT assesses only large-fiber function; it is a screening test, and neuropathy was not confirmed by nerve conduction studies or another independent diagnostic method. Foot ulcers, amputations, and quality of life were not assessed. Finally, measurements were made by more than one technician; although a standardized protocol was followed, inter-observer reliability was not assessed. Prospective studies that record diabetes duration and glycemic control and include age-matched controls are needed to confirm these findings.

Conclusions

The evaluation of VPTs in patients with T2DM showed elevated VPT, indicating impaired vibration perception, with abnormal great toe thresholds in nearly three-quarters of patients and a strong, consistent rise in VPT with age. Routine VPT assessment, particularly in older patients, may help identify those with impaired vibration perception. Prospective studies are needed to determine whether such screening improves foot outcomes and quality of life.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Deb Sanjay Nag, Ajay Jha, Abha Singh, Saukat Das, Ashok Sunder

Acquisition, analysis, or interpretation of data: Deb Sanjay Nag, Ajay Jha, Abha Singh, Saukat Das, Ashok Sunder

Drafting of the manuscript: Deb Sanjay Nag, Ajay Jha, Abha Singh, Saukat Das, Ashok Sunder

Critical review of the manuscript for important intellectual content: Deb Sanjay Nag, Ajay Jha, Abha Singh, Saukat Das, Ashok Sunder

Supervision: Deb Sanjay Nag, Ajay Jha, Abha Singh, Saukat Das, Ashok Sunder

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the

submitted work.

References

1. ElSayed NA, Aleppo G, Aroda VR, et al.: 1. Improving care and promoting health in populations: standards of care in diabetes-2023. Diabetes Care. 2023, 46:S10-8. 10.2337/dc23-S001
2. Rask-Madsen C, King GL: Vascular complications of diabetes: mechanisms of injury and protective factors . Cell Metab. 2013, 17:20-33. 10.1016/j.cmet.2012.11.012
3. Tesfaye S, Boulton AJ, Dyck PJ, et al.: Diabetic neuropathies: update on definitions, diagnostic criteria, estimation of severity, and treatments. Diabetes Care. 2010, 33:2285-93. 10.2337/dc10-1303
4. Vinik AI, Nevoret ML, Casellini C, Parson H: Diabetic neuropathy . Endocrinol Metab Clin North Am. 2013, 42:747-87. 10.1016/j.ecl.2013.06.001
5. Yang Y, Zhao B, Wang Y, Lan H, Liu X, Hu Y, Cao P: Diabetic neuropathy: cutting-edge research and future directions. Signal Transduct Target Ther. 2025, 10:132. 10.1038/s41392-025-02175-1
6. Jahantigh Akbari N, Hosseinifar M, Naimi SS, Mikaili S, Rahbar S: The efficacy of physiotherapy interventions in mitigating the symptoms and complications of diabetic peripheral neuropathy: a systematic review. J Diabetes Metab Disord. 2020, 19:1995-2004. 10.1007/s40200-020-00652-8
7. Zhao N, Xu J, Zhou Q, et al.: Application of the Ipswich Touch Test for diabetic peripheral neuropathy screening: a systematic review and meta-analysis. BMJ Open. 2021, 11:e046966. 10.1136/bmjopen-2020-046966
8. Subramani A, Periasamy P, Gunasekaran S: A comparative analysis of diagnostic accuracy: vibration perception threshold vs. diabetic neuropathy examination for diabetic neuropathy. J Pharm Bioallied Sci. 2024, 16:S4536-9. 10.4103/jpbs.jpbs_1160_24
9. Garrow AP, Boulton AJ: Vibration perception threshold--a valuable assessment of neural dysfunction in people with diabetes. Diabetes Metab Res Rev. 2006, 22:411-9. 10.1002/dmrr.657
10. Shen J, Liu F, Zeng H, et al.: Vibrating perception threshold and body mass index are associated with abnormal foot plantar pressure in type 2 diabetes outpatients. Diabetes Technol Ther. 2012, 14:1053-9. 10.1089/dia.2012.0146
11. Young MJ, Breddy JL, Veves A, Boulton AJ: The prediction of diabetic neuropathic foot ulceration using vibration perception thresholds. A prospective study. Diabetes Care. 1994, 17:557-60. 10.2337/diacare.17.6.557
12. Djankpa FT, Amoah AG, Adzaku FK, Aidoo E, Boateng I: Assessing the vibration perception threshold in a community sample of adult Ghanaians. PLoS One. 2023, 18:e0291606. 10.1371/journal.pone.0291606
13. Purwanti OS, Nursalam N, Pandin MG: Early detection of diabetic neuropathy based on health belief model: a scoping review. Front Endocrinol. 2024, 15:1369699. 10.3389/fendo.2024.1369699
14. ElSayed NA, Aleppo G, Aroda VR, et al.: 2. Classification and diagnosis of diabetes: standards of care in diabetes-2023. Diabetes Care. 2023, 46:S19-40. 10.2337/dc23-S002
15. Medakkel AA, Sheela P: Vibration perception threshold values and clinical symptoms of diabetic peripheral neuropathy. J Clin Diagn Res. 2018, 12:20-3. 10.7860/JCDR/2018/32825.11549
16. Kelshikar S, Athavale V, Parekh RA, Ranka M: The role of a biothesiometer in early detection and management of diabetic neuropathy. Cureus. 2024, 16:e70588. 10.7759/cureus.70588
17. Tang WH, Zhao YN, Cheng ZX, Xu JX, Zhang Y, Liu XM: Risk factors for diabetic foot ulcers: a systematic review and meta-analysis. Vascular. 2024, 32:661-9. 10.1177/17085381231154805
18. Boulton AJ, Vileikyte L, Ragnarson-Tennvall G, et al.: The global burden of diabetic foot disease . Lancet. 2005, 366:1719-24. 10.1016/S0140-6736(05)67698-2
19. Singh N, Armstrong DG, Lipsky BA: Preventing foot ulcers in patients with diabetes . JAMA. 2005, 293:217-28. 10.1001/jama.293.2.217
20. Nather A, Cao S, Chen JL, Low AY: Prevention of diabetic foot complications . Singapore Med J. 2018, 59:291-4. 10.11622/smedj.2018069
21. Arts ML, Waaijman R, de Haart M, Keukenkamp R, Nollet F, Bus SA: Offloading effect of therapeutic footwear in patients with diabetic neuropathy at high risk for plantar foot ulceration. Diabet Med. 2012, 29:1534-41. 10.1111/j.1464-5491.2012.03770.x
22. Smith S, Normahani P, Lane T, Hohenschurz-Schmidt D, Oliver N, Davies AH: Prevention and management strategies for diabetic neuropathy. Life. 2022, 12:1185. 10.3390/life12081185
23. Mohan V, Khunti K, Chan SP, et al.: Management of type 2 diabetes in developing countries: balancing optimal glycaemic control and outcomes with affordability and accessibility to treatment. Diabetes Ther. 2020, 11:15-35. 10.1007/s13300-019-00733-9
24. Zarora R, Immanuel J, Chivese T, MacMillan F, Simmons D: Effectiveness of integrated diabetes care interventions involving diabetes specialists working in primary and community care settings: a systematic review and meta-analysis. Int J Integr Care. 2022, 22:11. 10.5334/ijic.6025
25. Lee K: Effects of whole-body vibration therapy on perception thresholds of type 2 diabetic patients with peripheral neuropathy: a randomized controlled trial. J Phys Ther Sci. 2017, 29:1684-8. 10.1589/jpts.29.1684
26. Kazamel M, Stino AM, Smith AG: Metabolic syndrome and peripheral neuropathy . Muscle Nerve. 2021, 63:285-93. 10.1002/mus.27086