Review Article

Vibration Perception Threshold as Tool to Detect Neuropathy Diabetic: A Scoping Review

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ABSTRACT

Decreased foot sensitivity in diabetic neuropathy can be assessed using Vibration Perception Threshold (VPT). There are various types of VPT instruments for neuropathy examination. This study aims to analyze VPT to detect diabetic neuropathy. Data search in this study used Scopus, PubMed, ProQuest, Ebsco CINAHL, and DOAJ with the keywords "Vibration" AND "Neuropathy" AND "Diabetic." Article selection through rayyan.AI and recorded in PRISMA Flow-Chart. Article selection based on article title, type of research, and research topic. We determined the articles included in this study based on the year of publication 2019-2024, English language, full text, and open access. The eligibility criteria test used the JBI checklist for diagnostic accuracy, then for analysis using narrative analysis. A total of 17 of the 1959 articles screened met the inclusion criteria and were included in the final analysis using PICO. We found diabetic neuropathy examination instruments using tuning forks, VibraTip, biothesiometer, and neurothesiometer. The examination sites are metatarsal 1, 3, and 5; vibration on the heel of the foot, hallux, plantar, and big toe area. This procedure involves giving varying amounts of vibration. Based on our findings, VPT instruments have been widely used and are effective in detecting diabetic neuropathy. VPT instruments include biothesiometer, neurothesiometer, tuning fork, and VibraTip as an early detection program for diabetic neuropathy to prevent diabetic ulcers.

KEYWORDS: Early Detection, Examination, Instrument, Neuropathy Diabetic, Scoping Review, Vibration Perception Threshold.

INTRODUCTION

Diabetes mellitus is a metabolic disorder causing diabetic neuropathy and diabetic retinopathy. Diabetic neuropathy is the most common complication in diabetes mellitus with symptoms of decreased sensitivity in the feet [1]. The incidence of neuropathy in diabetes mellitus patients has reached 43.16% [2]. The prevalence of diabetic neuropathy in Qatar reached 23%, of which 33.7% were at high risk of developing diabetic ulcers, 6.3% suffer from ulcers, and 82% of patients were not previously diagnosed [3].

Diabetic neuropathy patients who do not receive regular neuropathy treatment will be at risk of developing diabetic ulcers and having amputations so that patients experience a decrease in quality of life [4]. Early examination and regular foot care are important to prevent the severity and complications of diabetic neuropathy [5]. Various methods of early detection diabetic neuropathy have been developed and applied in clinical practice such as the Michigan Neuropathy Screening Instrument (MNSI) [6], Toronto Clinical Neuropathy Score (TCNS) [7], clinical value of Shear Wave Elastography (SWE) [8], Retinal Nerve Fiber Layer (RNFL) [9], examination sensory neuropathy using monofilament 10g [10], and examination sensation of neuropathy diabetic using Vibration Perception Threshold (VPT) [11]. VPT is the gold standard for examining diabetic neuropathy and the risk of foot ulcers and assesses the vibration sensation in the patient's feet [12]. VPT instruments include a 128 Hz tuning fork, neurothesiometer, and 128Hz tuning fork biothesiometer [13].

The VPT check was carried out by providing vibrations of 0-50V in stages. Location of examination was at hallux, metatarsal, and arch. The patient said "yes" if he felt the vibration. Neuropathy results were positive if the patient felt vibrations >25V [14]. In previous research, the accuracy test for VPT examinations using a neurothesiometer showed that 95% of the diagnostic neurothesiometer were accurate [15]. The purpose of this scoping review is to evaluate VPT for detecting diabetic neuropathy.

METHODOLOGY

Research Design

We conducted a scoping review to identify and assess articles on the methods and accuracy of Vibration Perception Threshold (VPT) examination for diagnosis of diabetic neuropathy. The aim of our study was to understand the various methods used in VPT examination and evaluate how effective they are in detecting diabetic neuropathy.

Research Questions

The research question formulated is as follows: how does the VPT instrument detect diabetic neuropathy?

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Study Selection process

The article screening process through rayyan.AI through duplicate identification, title and abstract screening, and identification of relevant research through full text. We illustrate the article selection process in the PRISMA flow diagram [16]. Full article selection is based on PICO (Population, Intervention, Comparison, Outcome) analysis.

Exclusion criteria

Exclusion criteria consisted of research subjects with patient post-surgery and patient hemodialysis, article intervention decrease symptoms of neuropathy diabetic.

Search strategy and data charting

Searching through Scopus, PubMed, ProQuest, Ebsco CINAHL, and DOAJ databases with the keywords "Vibration" AND "Neuropathy" AND "Diabetic," we limited the search to 2019-2024 English language articles and open access. The data search strategy in this study began by looking at the article's title and abstract which refers to the topic of neuropathy diabetic diagnosis using VPT.

Quality assessment

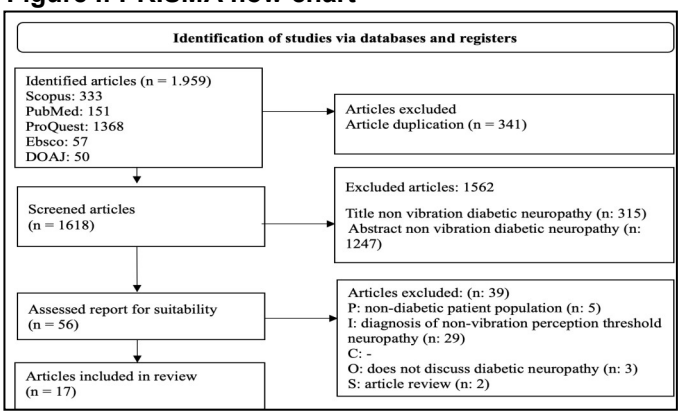
We used JBI diagnostic accuracy to assess the suitability of articles in our research. The set of eligibility criteria consisted of studies with case-control methods and cross-sectional studies. Questions consisted of 10 points 1,4,5,6,7,8,9,10 with 1 if the answer is "yes" in questions 2 and 3 worth 1 if the answer is "no." Questions on the JBI checklist included study design, measurement, and subject. The quality of the article is considered good if the points are >50% [17].

RESULTS

Screening results

The research screening process involved 1959 articles from five databases. After removing duplicates, we were left with 1618 articles. Next, we identified articles based on title and abstract resulting in 56 articles. Then we reviewed the full text of the articles based on the inclusion and exclusion criteria and we finally obtained 17 articles. We illustrated the article screening process in the PRISMA flow diagram which can be seen in **Figure I**.

Figure I: PRISMA flow chart



Quality assessment

We used JBI diagnostic accuracy to assess the suitability of articles included in this study. The suitability value of the articles in this research is more than 50%, so that all articles are suitable for research. The assessment can be seen in **Table I**.

Table I: Quality aassessment

Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total
18	1	1	1	0	1	1	1	1	1	1	9
19	1	1	1	1	1	0	1	0	1	1	8
20	1	1	1	1	1	1	1	1	1	1	10
21	1	1	1	1	1	1	1	1	1	1	10
22	1	1	1	1	0	0	1	1	1	1	8
23	1	1	1	1	1	1	1	1	0	1	9
14	1	0	1	1	1	1	1	1	1	1	9
24	1	1	1	1	0	0	1	1	1	1	8
25	1	1	1	1	1	1	1	0	1	0	8
26	1	1	1	1	1	1	1	1	1	1	10
27	1	1	1	1	1	1	1	0	1	1	9
28	1	0	1	1	1	0	1	1	0	1	7
29	1	1	1	1	1	1	1	1	1	1	10
30	1	1	1	1	0	0	1	1	1	1	8
31	1	1	1	1	0	0	1	1	1	1	8
32	0	0	1	1	0	0	1	1	1	1	6
33	1	1	1	1	1	1	1	1	1	1	10

Study characteristics

The 17 articles included in this research had different characteristics. The research design we used in this study was case-control and cross-sectional study. Diabetes mellitus patients involved in this study had various symptoms of complications so that it may increase insight into the VPT examination in detecting diabetic neuropathy. We wrote the analysis of the articles in this study in **Table II**.

Location, Procedure, and Accuracy of Instrument Diagnostic

We found six devices for VPT examination with different examination locations and procedures. We found the accuracy assessment of the six vibration devices, which showed that each device accurately detected diabetic neuropathy as shown in **Table IV**.

DISCUSSION

Diabetic neuropathy is the most common complication in diabetes mellitus sufferers and becomes the main cause of diabetic ulcers. Patients who experience diabetic neuropathy are at great risk of developing ulcers, gangrene and amputation [34] However, patients pay less attention to their condition so that symptoms of more serious complications appear [35]. Symptoms that commonly occur in diabetic neuropathy patients include numbness, tingling, and pain [36]. Early detection of neuropathy is important to prevent the risk of chronic complications in the community. Blood glucose levels and foot sensitivity are indications for establishing a diagnosis of diabetic

Table II: Article Analysis

Author	Study Design	Sample	Instrument	Analysis	Results
18	Cross-sectional study	100 patients DM	VibraTip and Diabetic Neuropathy Score	Youden's J Statistic	The performance of the VibraTip using various neuropathy examination protocols showed good sensitivity and specificity with the highest sensitivity value (100%) and very high specificity (96.8%).
19	Cross-sectional study	90 patients DM	Vibration II	Intraclass correlation coefficient	Results of the intraclass correlation coefficient (ICC) assessment for all patients were 0.958; with male patients it was 0.953; female patients amounted to 0.962; patients without obesity were 0.949; and patients with obesity of 0.975. This assessment showed that VPT had good reliability in detecting diabetic neuropathy.
20	Case control study	100 patients DM	Biothesiometer and monofilament 10g	Cohen's kappa test	Biothesiometer has been proven to be effective and reliable in detecting neuropathy diabetic, as indicated by a value of 0.96.
21	Cross-sectional study	562 patients DM	Vibrasense, biothesiometer, monofilament and Nerve Conduction Study	ROC	Vibrasense sensitivity was 82.14% and specificity was 78.79%. The ROC curve value of Vibrasense showed an area under curve (AUC) of 95%, indicating that Vibrasense had high accuracy in neuropathy examination.
22	Cross-sectional study	65 patients DM	Monofilament, tuning fork, biothesiometer	ANOVA test Cochran's test	Based on the ANOVA test, neuropathy examination using monofilament showed the longest time, using a tuning fork showed the fastest time, while using a biothesiometer was between the tuning fork and monofilament.
23	Cross-sectional study	143 patients DM	Corneal confocal microscopy, Neuropathy Disability Score, neurothesiometer, and neurosensory TSA II analysis	Fisher exact test and ROC	The VPT biothesiometer instrument was used as a comparison in assessing the performance of CCM in detecting diabetic neuropathy. The performance of CCM scanning in assessing neuropathy based on corneal confocal microscopy showed a sensitivity value of 55%, and a specificity of 90%, which showed that CCM can detect neuropathy based on the results of corneal confocal microscopy examination,
14	Cross-sectional study	66 patients DM	Neurothesiometer, Vibrasense, Nerve Conduction Study	Mann-Whitney U-test/ Chi-square, and ROC	The ROC curve value showed a sensitivity of 79% and a specificity of 76%. Neuropathy examination using vibration was proven to be accurate.
24	Cross-sectional Study	1741 patients DM	Neurothesiometer, Nerve Conduction Study	ANNOVA test and ROC	ROC analysis in this study was to determine the accuracy of VPT in detecting neuropathy that affected gait. The AUC value on the ROC curve was 0.608 (95%).
25	Cross-sectional study	50 patients with diabetes mellitus	Monofilament and neurothesiometer and tuning fork	Cohen's kappa test	Reliability assessment of neuropathy examination using three instruments: neurothesiometer 95%, monofilament 95%, and tuning fork 95%.
26	Cross-sectional study	421 patients DM	Neurothesiometer	ROC	The measurement of the AUC value on the ROC curve shows a sensitivity of 67% and a specificity of 85.1%. This shows that VPT is accurate in neuropathy examination.
27	Cross-sectional study	34 patients DM	Monofilament, Tuning fork and Toronto Clinical Neuropathy Score	Intra-class Correlation Coefficient and intra-rater reliability	The reliability assessment of the vibration instrument in one day using a tuning fork was 0.92 (256Hz) and 0.82 (128Hz) and the reliability assessment between several days showed a value of 0.71 (128Hz).
28	Cross-sectional study	289 patients DM	Biothesiometer, tuning fork and nerve conduction studies	ROC	The results of the diagnostic value of diabetic neuropathy using a biothesiometer had a sensitivity of 47% and a specificity of 77%, using a tuning fork a sensitivity of 58% and a specificity of 74%.
29	Cross-sectional study	patients DM	VibraTip, tuning fork, and monofilament	ROC	VibraTip sensitivity value showed 95%, which means that VibraTip can detect neuropathy accurately.
30	Cross-sectional study	75 patients DM	Monofilament 10g, VibraTip and biothesiometer	Chi-square test, independent t-test analysis.	The VibraTip performed very well with a positive predictive value of 90.3% and specificity of 84.2% when compared with the biothesiometer.
31	Cross-sectional study	696 patients DM	Biothesiometer	Levenberg–Marquardt	Biothesiometer is an effective technique and tool for assessing diabetic feet through VPT examination. Classification of patients based on severity (diabetic neuropathy) of DN and magnitude of VPT for further analysis and providing information for artificial neural network (ANN) construction model network.
32	Cross-sectional study	108 patients DM	Tuning fork	According to the Cox proportional hazard analysis	Comparison between elderly people and diabetic peripheral neuropathy patients showed patients with diabetic peripheral neuropathy had significantly lower pressure-touch sensitivity compared with elderly people.
33	Cross-sectional study	242 patients DM	Michigan Neuropathy Scoring Instrument, Biothesiometer, and TRC NW 300 mydriatic fundus camera	ROC and Cohen's kappa value	ROC curve-based assessment showed VPT sensitivity of 80% and specificity of 92%, central retinal vein equivalent (CRVE) sensitivity of 55% and specificity of 93%, fractal dimension arterioles (DFa) sensitivity of 82% and specificity of 82% and fractal dimension equivalent (DFv) sensitivity 67% and specificity 80%. Based on this assessment, VPT, CRVE, DFa, and DFe were accurate in detecting diabetic neuropathy.

DM: Diabetes Mellitus; ROC: Receiver Operating Characteristic

Table III: Location, Procedure, and Accuracy of Instrument Diagnostic

Author	Instrument VPT	Examination Locations and Procedures	Diagnostic Accuracy Assessment
14,24, 25,26	Neurothesiometer	Diabetic neuropathy examination using neurothesiometer at the location of the peak of the hallux, the distal pulp of the left big toe. The examination position of the foot resting on the floor with a vibration of 0-50V. Instruct the patient to give a signal if they feel vibrations. The results indicate neuropathy if they do not feel vibrations >25V.	Based on the measurement of the AUC value on the ROC curve, the sensitivity of the VPT instrument was 67% and the specificity of the VPT instrument was 85.1%. This showed that VPT was accurate in examining neuropathy.
20, 22, 23, 28, 30, 31, 33	Biothesiometer	The examination location at six points namely plantar, hallux, metatarsal head 1, metatarsal head 3, metatarsal head 5, instep, and heel. The magnitude of the vibration is 0-50V. Before the examination begins, give an example of vibration sensation to the patient. Instruct the patient to signal if they feel the vibration. Positive neuropathy assessment if they do not feel vibration >25V.	Neuropathy examination used a monofilament and a biothesiometer and showed the same value, namely (0.96), so that both instruments were reliable and effective in examining neuropathy.
27, 28, 32	Tuning fork	Examination location using a 128Hz tuning fork on the thumb; the patient's position is supine on the bed. Examination time for 10 seconds. The patient is asked to give a sign to the examiner when the patient feels a vibration. The patient is considered abnormal if he does not feel the vibration.	Reliability assessment of instrument vibration in one day using a tuning fork of 0.92 (256 Hz) and 0.82 (128 Hz) and reliability assessment over several days showed a value of 0.71 (128 Hz).
18,29	VibraTip	The VibraTip device provides a constant vibration stimulus of 128 Hz. The location of the neuropathy examination is at the hallux pulp, first metatarsal, and third metatarsal. The testing stage involves placing it parallel to the skin of the big toe for 10-20 seconds based on the manufacturer's usage guidelines. Neuropathy is declared positive if the patient does not feel vibration at 1 or more points.	Based on the diagnostic value of VibraTip, the sensitivity value was 95% so that VibraTip can detect neuropathy accurately.
21	Vibrasense	Perform a Vibrasense examination on metatarsal 1 and metatarsal 5 with gradual frequencies ranging from 4, 8, 16, 32, 64, 125, to 250 Hz. The patient is asked to press the button if he feels a vibration.	Vibrasense sensitivity was 82.14% and specificity was 78.79%. The ROC value of Vibrasense showed an AUC of 95% so that Vibrasense had high accuracy for examining neuropathy.
19	Vibration II	Measuring using Vibration II that consists of two parts, such as the vibration control section and wo vibration modules. The controller device has a layer that displays the vibration amplitude, a vibration controller, and four switches. The module vibrates at a frequency of 120 Hz.	VPT reliability assessment using intraclass correlation coefficient (ICC) analysis on 90 patients with a value of 0.958, male patients 0.953, female patients 0.962, patients without obesity 0.949, patients with obesity 0.975. This assessment showed that VPT had good reliability in detecting diabetic neuropathy.

neuropathy[37]. Determining the value of diabetic neuropathy through sensory neuropathy examination can be achieved using monofilament 10 gr [38]. Classification of signs and symptoms of patients with blood glucose disorders in diabetic neuropathy use the vibration perception threshold (VPT) [39]. VPT becomes the gold standard in diagnosing diabetic neuropathy [40]. We found that the biothesiometer is the most widely used VPT instrument using vibration of 1-50V and the results of the examination were positive neuropathy >25V. This scoping review research focuses on inspection methods and accuracy of VPT instruments.

Location and Procedures Examination

Based on the results of the study in Table IV, various neuropathy examination instruments using VPT are seen. Six VPT instruments were found that can be used to detect diabetic neuropathy. Each instrument instructs the patient to close their eyes during the examination and respond when they feel vibrations.

The patient's position is sitting during the VPT examination using a neurothesiometer, the feet rest on the floor with a vibration magnitude of 50 Hz [14]. The patient is in the supine position when examining the 128 Hz tuning fork [32]. In another study, the location of the neurothesiometer examination on the hallux with vibrations of 0-50V resulted in an abnormal examination if the patient did not feel vibrations >25V. Researchers carried out an examination using a 128 Hz tuning fork at the same location, the examination results were abnormal if the patient did not feel vibrations [25]. Another study employed an instrument for assessing vibration perception threshold connected to a smartphone; the design of the tool resembled a tuning fork integrated into the smartphone[39].

The VPT examination used a biothesiometer with the patient supine and provides vibrations at six points: plantar, hallux, 1st metatarsal head, 3rd metatarsal head, 5th metatarsal head, instep and heel. The magnitude of the vibration can increase gradually, indicating positive neuropathy if the vibration threshold is > 25 mV [20]. In contrast to other studies, the VPT examination location used a biothesiometer on the pulp of the thumb and repeated the examination three times on each foot[33]. Diabetic neuropathy examination

using biothesiometer has been proven to be a superior and accurate examination, but it is an expensive tool. A study stated that a tuning fork is a practical and economical tool as a substitute for a biothesiometer[41]

VPT examination using vibrating implements two protocols: protocol A with the examination location only on the hallux pulp, and protocol B with the examination location on the hallux pulp, metatarsal 1st and metatarsal 3rd. Based on these two protocols, the patient experiences neuropathy if there is no feeling at one or more points [18]. Researchers gave a constant 128 Hz vibration stimulus to the big toe for 10-20 seconds[30].

Vibrasense detects neuropathy in metatarsal 1st and metatarsal 5th with frequencies (4, 8, 16, 32, 64, 125, and 250 Hz). Before the examination took place, researchers instructed patients to press a button if they felt vibrations [14]. Combining vibration perception threshold examination frequencies using Vibrasense shows accurate detection at the two largest and two smallest frequencies; we found the strongest correlation at a frequency of 125 Hz. The frequency of 125 Hz in clinical practice is almost the same as a tuning fork at 128Hz. However, this frequency does not align with the ideal sensitivity of the Pacinian and Meissner cells that function as vibration receivers [42]

The Vibration II instrument consists of two parts: vibration controller and vibration module. The Vibration II module provides vibrations at a frequency of 120 Hz [19]. We also found the Vibration Sensory Analyzer 3000 (VSA 300) is an accurate tool in early detection of diabetic neuropathy. The VSA 3000 is connected to a computer to display the results of examination. The procedure of examination uses the VSA 3000 at a vibration frequency of 100Hz in the toe, 1st metatarsal, 5th metatarsal, and heel [43].

Accuracy of Instrument Diagnostic

Previous research had discussed the diagnostic assessment of VPT. This diagnostic assessment is important to determine the accuracy of the instrument in the diagnosis of neuropathy. We found the accuracy value of each instrument in the VPT examination.

The results of ROC curve analysis in assessing the diagnostic accuracy of the neurothesiometer were 95%. The accuracy of the neurothesiometer compared to monofilament and tuning fork had the same reliability value, namely 95%. The assessment of the biothesiometer instrument using Cohen's kappa analysis has a reliability value of 0.96[20].

The results of the Vibrasense diagnostic assessment in 380 patients using ROC analysis had a sensitivity of 82.5% and a specificity of 78.79%[21]. ROC assessment on the vibrating instrument showed a sensitivity of 95%[29]. Instrument diagnostic assessment using ROC analysis shows an accurate assessment if the value is >50% and assessment using Cohen's kappa analysis shows accuracy if the value is 0.81-1.00. Based on this assessment, the neurothesiometer, biothesiometer, tuning fork, VibraTip and Vibrasense instruments are accurate in diagnosing diabetic neuropathy.

The results of assessing the accuracy of Vibration II using intraclass correlation coefficient (ICC) analysis in 90 patients were 0.958, male patients 0.953, female patients 0.962, patients without obesity 0.949, patients with obesity 0.975. This assessment shows that Vibration II has good reliability. However, Vibration II instruments are still rarely used in health services [19]. All instruments included in this study have good diagnostic value, so that all instruments are accurate in diagnosing diabetic neuropathy.

CONCLUSION

Vibration Perception Threshold (VPT) is the gold standard examination in the diagnosis of diabetic neuropathy. VPT has been widely used and is effective for detecting diabetic neuropathy. Commonly used VPT instruments are a biothesiometer, neurothesiometer, tuning fork, and VibraTip as an early detection program for diabetic neuropathy so that it can prevent diabetic ulcers. The neuropathy instruments that we found in this study have different procedures and examination locations, but all VPT instruments in this study showed good diagnosis test values and are reliable for diagnosing diabetic neuropathy. Based on the variation in results found across studies, we recommend multicenter studies involving multiple sites and populations to confirm our findings and expand our understanding of the effectiveness of VPT in different contexts.

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AUTHOR CONTRIBUTION

Purwanti OS: Conceptualization, Investigation, Methodology, Resources, Software, Visualization, Writing original draft, review & editing.

Nursalam N: Supervision, Validation, Original draft, writing review & editing and Methodology.

Wahyudi AS: Supervision, Validation, writing original draft, writing review & editing.

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