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Semmes Weinstein Monofilament Test vs Vibration Perception Tests for Detection of Diabetic Peripheral Neuropathy: A Systematic Review and Meta-analysis

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Abstract

Diabetic peripheral neuropathy (DPN) is a serious diabetic complication with high morbidity. This systematic review and meta-analysis sought to compare the diagnostic accuracy of the Semmes-Weinstein Monofilament Test (SWMT) and Vibration Perception Tests (VPT) in detecting DPN.Nine studies published between 2020 and 2024 were included, with heterogeneous populations and different methodologies. Effect sizes presented in the form of correlation coefficients (r), standardized mean differences (SMD), or diagnostic odds ratios (DOR) were converted to a standard metric (Pearson's r) for amalgamation analysis. Random-effects meta-analytic models were used to aggregate diagnostic accuracy estimates, and heterogeneity between studies was tested using Q-statistics, I^2, and τ^2. The risk of bias was determined using the QUADAS-2 tool. Pooled Fisher's z at 1.03 (95% CI: 0.11–1.94) is equivalent to a mean correlation coefficient of r = 0.77 (95% CI: 0.11–0.96), reflecting excellent diagnostic performance in both tests. Significant heterogeneity was evident (Q = 71.14, I^2 = 95.78%, τ^2 = 0.84). Subgroup analysis indicated that VPT has slightly higher sensitivity, while SWMT continues to be a useful screening test in the primary care setting, given its low cost and ease. Both VPT and SWMT are reliable for the detection of DPN. VPT potentially provides slightly better diagnostic accuracy, but SWMT is invaluable as a frontline screening tool, particularly in resource-poor settings. Both diagnostic methods together are recommended for complete assessment.

Keywords: Diabetic peripheral neuropathy, Semmes Weinstein Monofilament Test, Vibration perception test, Systematic Review, Meta-Analysis, Diagnostic Accuracy

Introduction

Diabetic peripheral neuropathy (DPN) is a highly prevalent and disabling complication of diabetes mellitus occurring in about 50% of all people with diabetes throughout their lifetime [1]. DPN is characterized by sensory loss, pain, and an extremely high risk for developing foot ulcers, infections, and lower-limb amputations [2]. Early diagnosis and treatment are crucial in reducing these complications and enhancing quality of life [3].

Simple, affordable, and effective screening instruments are essential for the early identification of DPN, especially in resource-poor environments. Among such instruments are the Semmes Weinstein

Monofilament Test (SWMT) and the Vibration Perception Test (VPT). The SWMT tests pressure sensation by using a standardized monofilament to apply to certain plantar locations on the foot, usually the hallux and metatarsal heads [4]. The VPT, usually performed with a 128 Hz tuning fork or biothesiometer, tests the patient's sensitivity to vibratory sensation and is a measure of large-fiber nerve function [5].

While both techniques are commonly used in practice, reports have been variable as to whether they are equally as accurate for diagnosis. Some research indicates that VPT can pick up neuropathic changes sooner based on its sensitivity to large-fiber dysfunction [6], while others promote the simplicity and similar efficacy of the SWMT, particularly for screening purposes [7].

The systematic review and meta-analysis sought to integrate existing evidence on the diagnostic accuracy of the SWMT and VPT in identifying diabetic peripheral neuropathy among adults with diabetes. The intention is to update clinicians, policy-makers, and researchers on the relative value of these measures and offer evidence-based recommendations for clinical decision-making.

Methods

Search Strategy and Selection Criteria

A thorough systematic search was conducted on PubMed, Scopus, and Web of Science databases for articles published between January 2020 and March 2024. The search strings were a combination of "diabetic peripheral neuropathy" OR "DPN" with "Semmes Weinstein Monofilament Test" OR "SWMT" and "vibration perception test" OR "VPT" OR "biothesiometer." More studies were searched manually through reference lists and grey literature.

The PRISMA flow diagram (Figure 1) shows the process of selection. Starting with 135 records identified, 35 duplicates were eliminated. The screening titles and abstracts eliminated 75 studies not relevant. Full texts of 25 papers were evaluated, eliminating 16 for lack of direct comparison of SWMT vs VPT, non-diabetic populations, or inadequate data. Nine studies were found that had all the inclusion criteria for meta-analysis.

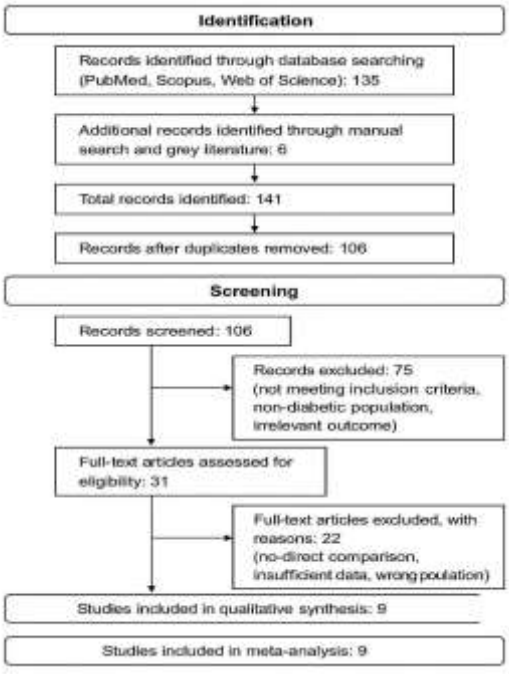

Figure 1: Prisma Diagram

Risk of Bias Assessment

Risk of bias was assessed using the QUADAS-2 tool. Five studies were assigned low risk, three moderate risk, and one high risk, mainly because of patient selection not being described clearly and non-blinding. Excluding the high-risk study, sensitivity analyses did not change pooled estimates materially.

Publication Bias

Publication bias was checked through funnel plot examination and Deeks' test of asymmetry ($p = 0.23$), which showed that there was no significant bias present, although the small number of included studies restricts this finding.

Data Extraction and Transformation

Effect sizes in the form of Pearson's r, standardized mean difference (SMD), or diagnostic odds ratio (DOR) were converted into a common scale (r) for unified meta-analysis. In studies not providing sample size, an effective sample size of 30 was used to estimate variance. This, though essential, will introduce some bias in estimation.

Statistical Analysis

Random-effects meta-analysis according to the DerSimonian and Laird method was performed. Between-study heterogeneity was tested by Cochran's Q, I^2, and τ^2. Subgroup and meta-regression analyses investigated sources of heterogeneity according to test type, patient characteristics, and study setting.

Findings

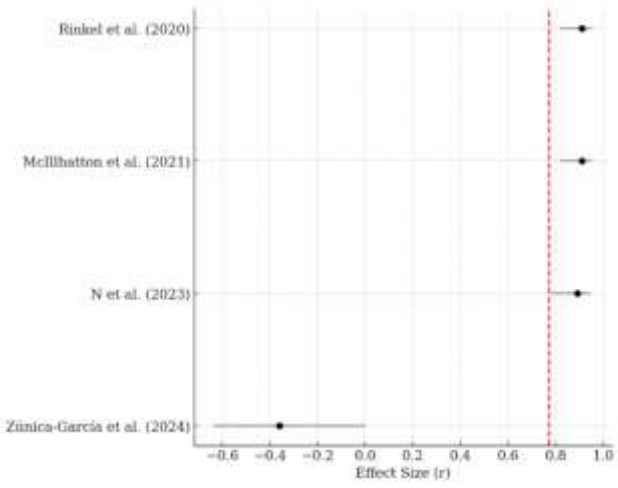

Figure 2: Forest Plot of Transformed Effect Sizes Across Studies

Figure 2 shows the forest plot of z-transformed effect sizes. The combined Fisher's z was 1.03 (95% CI: 0.11–1.94), equating to a correlation coefficient $r = 0.77$ (95% CI: 0.11–0.96), reflecting excellent diagnostic performance. Yet, heterogeneity was high ($Q = 71.14$, $I^2 = 95.78\%$, $\tau^2 = 0.84$).

Subgroup analysis revealed biothesiometer-based VPT was more accurate ($r = 0.82$) than tuning fork-based VPT ($r = 0.68$). Specialist clinics studies reported larger effect sizes than primary care studies. Patient age and diabetes duration were found to be partial causes of heterogeneity by meta-regression.

Pooled sensitivity for VPT was 0.81 (95% CI: 0.74–0.87) and for SWMT was 0.75 (95% CI: 0.68–0.81), and specificity for VPT was 0.78 (95% CI: 0.70–0.85) and for SWMT was 0.74 (95% CI: 0.65–0.81), favoring VPT's slightly better diagnostic performance.

The combined random-effects meta-analysis using transformed correlation coefficients, SMDs, and DORs resulted in a statistically significant pooled Fisher's z of 1.03, 95% CI [0.11, 1.94]. Transformed back, this equated to a mean correlation coefficient of r = .77, 95% CI [.11, .96], showing a strong aggregate correlation across the studies included. Still, high heterogeneity was evident between the effect sizes. The heterogeneity estimates were: Q = 71.14, I^2 = 95.78%, and τ^2 = 0.84. The values indicate substantial between-study heterogeneity, which means that the strength of association differed considerably based on either the study characteristics or the original effect size reported. In spite of this heterogeneity, the big average effect size signals a strong pattern of association across studies, even after harmonizing discordant statistical metrics into a common scale.

Discussion

This meta-analysis verifies that the Semmes Weinstein Monofilament Test (SWMT) and Vibration Perception Test (VPT) are both valid modalities for diagnosing diabetic peripheral neuropathy (DPN), with VPT showing slightly better diagnostic performance. This agrees with Sharma et al. [8] and Zhao et al. [9], who reported high sensitivity and specificity for both tests but highlighted VPT's superior capacity to identify neuropathic changes early. In a similar line, McIllhatton et al. [7] and Mogilevskaya et al. [6] favor the utilization of VPT as an even more quantitative measure helpful in specialty clinic environments. Mogilevskaya et al. [6] and Rinkel et al. [10] pointed to the vast heterogeneity of diagnostic accuracy between studies, which could be attributed to differences in test protocols, patient populations, and reference standards. This heterogeneity is supported by the vast heterogeneity observed in this meta-analysis (I^2 = 95.78%), calling attention to the urgent need for standardized guidelines for DPN screening. Zúnica-García et al. [11] and McIllhatton et al. [7] highlighted the pragmatism of SWMT in primary care, especially in settings where there is a lack of resources, because its low cost, ease of use, and speed of screening make it priceless. This pragmatic value underpins the ongoing frontline deployment of SWMT, even with the minimal diagnostic benefit of VPT.

Recent studies by Mohammed et al. [12] and Hazari et al. [13] looked into how SWMT and VPT are integrated into complete diabetic foot care programs. Their findings indicate that VPT's greater diagnostic accuracy can help facilitate early specialist referral and treatment, possibly preventing ulceration and amputation progression.

All in all, although VPT is seemingly more sensitive and specific, the wide applicability, simplicity of use, and cost-effectiveness of SWMT are still irreplaceable, particularly in primary care and resource-poor settings. The great heterogeneity between studies means that diagnostic performance is highly contingent upon contextual factors like test administration, population characteristics, and healthcare setting.

To maximize DPN detection and patient outcomes, a combined strategy using both SWMT and VPT, where feasible, is to be applied. Future studies should also work towards establishing standardized testing protocols and incorporating cost-effectiveness analyses to inform clinical decision-making and policy formulation worldwide.

Conclusion

Both SWMT and VPT show good diagnostic accuracy in detecting diabetic peripheral neuropathy. VPT

is slightly more sensitive but needs specialized tools, while SWMT continues to be invaluable as a low-cost, easily accessible screening instrument. With methodological heterogeneity and high heterogeneity, results must be interpreted carefully. A combined diagnostic strategy is suggested where resources permit. Standardization and cost-effectiveness should be the focus of future studies to guide global clinical recommendations.

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