



Review Article

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Effects of Wearable Vibration Therapy on Foot Perfusion, Neuropathy, and Wound Healing in Adults with Type 2 Diabetes: Systematic Review

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Abstract

Background: Type 2 diabetes mellitus (T2DM) is a major global cause of lower-extremity complications, including diabetic peripheral neuropathy (DPN), impaired foot perfusion, and diabetic foot ulcers (DFUs). Wearable vibration-based devices have emerged as non-pharmacological adjuncts to improve microcirculation, sensation, balance, and wound healing; however, evidence remains fragmented. **Objective:** To synthesize the effects, safety, and feasibility of wearable vibration-based therapies across perfusion, neuropathy, functional, and wound-healing outcomes in adults with T2DM. **Methods:** A systematic review was conducted following PRISMA 2020 and SWiM guidelines. Four databases (Scopus, PubMed, ScienceDirect, and SAGE Journals) were searched (2016–2026). Eligible studies included adults with T2DM receiving vibration-based interventions. Two reviewers independently screened and extracted data. Risk of bias was assessed using RoB 2, ROBINS-I, and CASP. **Results:** Thirteen studies (n ≈ 370) were included. Eleven reported favorable outcomes. Interventions improved vibration perception threshold, ankle-brachial index, skin blood flow, plantar sensation, balance, gait, and neuropathic pain. Adjunct vibration therapy accelerated DFU healing by approximately 8 days and increased nitric oxide levels. No serious adverse events were reported. **Conclusions:** Wearable vibration-based therapies appear to be safe and may provide short-term improvements in perfusion, sensory function, balance, and wound healing in adults with T2DM. However, larger well-designed studies are required to confirm long-term effectiveness.

Keywords: Foot perfusion; Microcirculation; Peripheral neuropathy; Type 2 diabetes mellitus; Vibration therapy.

تأثيرات العلاج بأجهزة الاهتزاز على تروية القدم، والاعتلال العصبي، وشفاء الجروح لدى البالغين المصابين بالسكري من النوع الثاني: مراجعة منهجية الخلاصة

الخلفية: مرض السكري من النوع الثاني (T2DM) هو سبب رئيسي لمضاعفات الأطراف السفلية، بما في ذلك الاعتلال العصبي المحيطي السكري (DPN)، وضعف تروية القدم، وقرح القدم السكري (DFUs). ظهرت أجهزة قابلة للارتداء تعتمد على الاهتزاز كإضافات غير دوائية لتحسين الدورة الدموية الدقيقة، والإحساس، والتوازن، وشفاء الجروح؛ ومع ذلك، لا تزال الأدلة مجزأة. **الهدف:** توليف تأثيرات وسلامة وجدوى العلاجات المعتمدة على أجهزة الاهتزاز عبر نتائج التروية، والاعتلال العصبي، والوظيفية، والشفاء للجروح لدى البالغين المصابين بالسكري من النوع الثاني. **الطرائق:** أجريت مراجعة منهجية وفقا لإرشادات PRISMA 2020 وSWiM. تم البحث في أربع قواعد بيانات (Scopus، PubMed، ScienceDirect، وSAGE Journals) (2016–2026). شملت الدراسات المؤهلة البالغين المصابين بالسكري من النوع الثاني الذين تلقوا تدخلات قائمة على الاهتزاز. قام مراجعان بفحص واستخراج البيانات بشكل مستقل. تم تقييم خطر التحيز باستخدام RoB 2، ROBINS-I، وCASP. **النتائج:** تم تضمين ثلاثة عشر دراسة (عدد الدراسات ≈ 370). أبلغ أحد عشر منهم عن نتائج إيجابية. حسنت التدخلات عتبة إدراك الاهتزاز، مؤشر الكاحل-العصدي، تدفق الدم في الجلد، الإحساس الأحمصي، التوازن، المشي، والألم العصبي. العلاج الاهتزازي الإضافي سرع شفاء DFU بحوالي 8 أيام وزاد من مستويات أكسيد النيتريك. لم يتم الإبلاغ عن أي أحداث جانبية خطيرة. **الاستنتاجات:** العلاجات القابلة للارتداء القائمة على الاهتزاز آمنة وفعالة لتحسين قصير الأمد في التروية، والإحساس، والوظيفية، وشفاء الجروح في السكري من النوع الثاني، مما يدعم دمجها في ممارسة التمريض. هناك حاجة إلى المزيد من التجارب واسعة النطاق.

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) represents a major global health challenge, affecting approximately 589 million adults worldwide in 2024 and projected to exceed 850 million by 2050 [1]. This rapid increase places a substantial burden on healthcare systems, particularly in the management of chronic complications [2–4]. Among these, lower-extremity complications—including diabetic peripheral neuropathy (DPN), impaired foot perfusion, and diabetic foot ulcers (DFUs)—are among the most debilitating and costly [5–8]. The lifetime risk of DFU

ranges from 19% to 34%, with amputation-related mortality rates surpassing those of several common cancers [9–11]. Conventional preventive strategies such as foot screening, pressure offloading, glycemic control, and patient education remain essential but demonstrate limited effectiveness in real-world settings due to poor adherence and the often asymptomatic nature of early neuropathy [12–14]. Consequently, there is increasing interest in non-pharmacological adjuncts that directly target peripheral circulation and sensory function, particularly within nursing-led care models [15–17]. Wearable vibration-based technologies, including vibrating insoles,

stochastic resonance foot orthoses, focal muscle vibration devices, and whole-body vibration platforms, have emerged as promising innovations. These technologies integrate principles of rehabilitation engineering with self-care interventions [18–21]. Mechanistically, vibration may enhance plantar sensory input through stochastic resonance, improve endothelial function via nitric oxide release, increase microvascular perfusion, and stimulate neuromuscular activation to improve balance and gait [22–24]. Although prior reviews have examined specific modalities such as whole-body vibration or smart wearable technologies, there remains a lack of comprehensive synthesis integrating multiple vibration modalities across key clinical outcomes [25–30]. Moreover, existing reviews have not sufficiently addressed these interventions from a nursing practice perspective or systematically evaluated evidence quality using contemporary appraisal tools [15,31]. Therefore, this systematic review aims to synthesize the effects, safety, and feasibility of wearable vibration-based therapies across perfusion, neuropathy, functional, and wound-healing outcomes in adults with T2DM. This synthesis is intended to inform evidence-based integration of these technologies into clinical nursing practice and guide future research.

METHODS

Study design and reporting

This systematic review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [32] and followed the Synthesis Without Meta-analysis (SWiM) reporting framework [33].

Eligibility criteria

Studies were selected based on the PICOS framework: Population, adults (≥ 18 years) diagnosed with T2DM. Studies involving mixed populations were included only if T2DM-specific data were extractable. Intervention: Wearable vibration-based devices applied to the lower extremities, including local plantar vibration, vibrating insoles, vibrating orthoses, focal muscle vibration, and whole-body vibration. Comparator, standard care, placebo or sham intervention, alternative therapy, no intervention, or baseline comparison. Outcomes, Measures of foot perfusion (e.g., ankle-brachial index, skin blood flow), neuropathy (e.g., vibration perception threshold, pain), functional outcomes (e.g., balance, gait), wound healing, safety, and feasibility. Study Design, Randomized controlled trials, crossover trials, quasi-experimental studies, single-arm interventions, pre-post studies, and case studies. Studies were limited to English-language publications between 2016 and 2026. Exclusion criteria included non-wearable interventions, non-T2DM populations without

separable data, review articles, protocols without results, and studies lacking full-text access.

Information sources and search strategy

A comprehensive literature search was conducted in Scopus, PubMed, ScienceDirect, and SAGE Journals [34]. Additional studies were identified through manual searches of reference lists and relevant reviews. The search strategy combined keywords related to diabetes, lower-extremity outcomes, vibration therapy, and wearable devices.

Study selection

All retrieved records were imported into Rayyan for screening and duplicate removal [35]. Two independent reviewers screened titles, abstracts, and full texts against the eligibility criteria. Inter-rater reliability was high (Cohen's $\kappa = 0.82$). Discrepancies were resolved through discussion or consultation with a third reviewer.

Ethical considerations

The study protocol was approved by the local Research Ethics Committee of the Faculty of Nursing, Jenderal Soedirman University, Indonesia (certificate 022/KEP.ITEKESMA/I/2026).

Data extraction

Data were extracted using a standardized form, including study characteristics, participant demographics, intervention details, outcome measures, and adverse events. Extraction was performed independently by two reviewers, with consensus used to resolve discrepancies.

Risk of bias assessment

Methodological quality was assessed using design-specific tools: the Cochrane Risk of Bias tool (RoB 2) for randomized trials [36], ROBINS-I for non-randomized studies [37], and the CASP checklist for qualitative or case studies. Two reviewers conducted assessments independently.

Data synthesis

Due to heterogeneity in study designs, interventions, and outcome measures, meta-analysis was not feasible. Instead, a structured narrative synthesis was conducted following SWiM guidelines [38]. Studies were grouped by intervention type and outcome.

RESULTS

Figure 1 demonstrates the study flow.

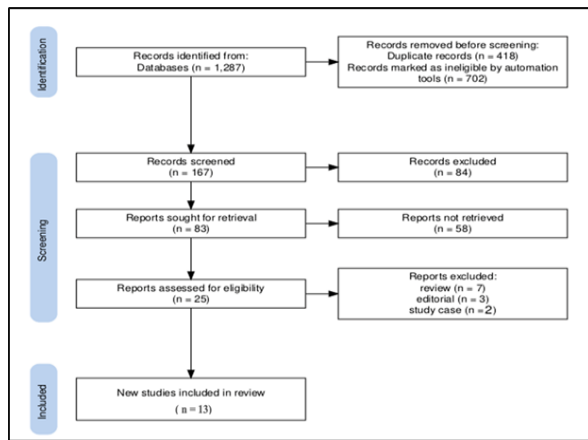


Figure 1: PRISMA flow diagram.

A total of 1,287 records were identified from database searches. After removing duplicates and ineligible records, 167 studies were screened, with 84 excluded. Of the 83 reports sought for retrieval, 58 were not obtained. From the 25 full-text articles assessed, 12 were excluded due to being reviews, editorials, or case studies. Finally, 13 studies met the inclusion criteria and were included in the review, reflecting a systematic and rigorous selection process. As shown in Table 1, randomized controlled trials indicate that vibration-based interventions, particularly whole-body vibration, improve neuropathy symptoms and functional outcomes in patients with type 2 diabetes mellitus while remaining safe and feasible, although evidence for perfusion and metabolic effects is less consistent.

Table 1: Characteristics of included studies

Author (year)	Study Design	Sample (n)	Intervention	Duration/Dose	Key Findings
Waheed <i>et al.</i> (2021) [44]	Single-blind RCT	40	Whole-body vibration + balance training	3 weeks, 3×/week	↑ muscle strength, ↑ balance, ↓ neuropathy score
Sohrabzadeh <i>et al.</i> (2022) [72]	RCT	30–40	Whole-body vibration	Single session	↑ balance, ↓ neuropathic pain, ↑ sensory function
Kosaji <i>et al.</i> (2025) [15]	Double-blind RCT	≈ 30	Whole-body vibration training	8 weeks	↑ glycemic control (HbA1c), ↑ physical fitness
Ramachandran <i>et al.</i> (2021) [91]	Single-blind RCT	≈ 30	WBV + exercise training	8 weeks	↑ glycemic control, ↑ lipid profile
Binesh <i>et al.</i> (2024) [46]	RCT	≈ 30	Whole-body vibration	Acute (short-term)	↑ foot perfusion, ↑ tissue oxygenation
Lee (2017) [53]	RCT	≈ 40	Whole-body vibration vs Tai Chi	8–12 weeks	↑ balance, ↑ functional independence
Albert <i>et al.</i> (2025) [80]	RCT	20	Whole-body vibration	4 weeks, 3×/week	↑ balance, ↑ functional performance
Hasan <i>et al.</i> (2024) [31]	RCT	≈ 50	Whole-body vibration training	12 weeks	↓ HbA1c, ↑ metabolic control
Niajalili <i>et al.</i> (2026) [45]	RCT	42	WBV + cognitive training	8 weeks	↑ balance, ↑ plantar sensation
Eraydin & Avsar (2018) [81]	RCT	≈ 60	WBV + vascular exercise	Not reported	↑ circulation, ↓ pain
Nayak <i>et al.</i> (2024) [54]	RCT	≈ 30	Whole-body vibration	Acute	↑ muscle strength, ↑ balance
Orlando <i>et al.</i> (2024) [73]	RCT crossover	≈ 25	Single-session WBV	Acute	↑ vibration perception threshold
Bashir <i>et al.</i> (2025) [47]	RCT	≈ 40	WBV + conventional therapy	4–8 weeks	↑ balance, ↓ pain, ↑ functional outcomes

Figure 2 shows the Cochrane traffic light plot showing risk of bias across included studies and domains. Green indicates low risk, and yellow indicates some concerns.

some concerns mainly observed in intervention and randomization domains.

DISCUSSION

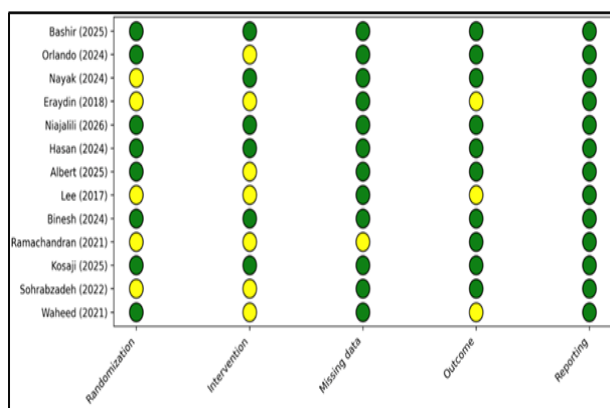


Figure 2: Risk of bias.

The present review demonstrates that vibration-based interventions provide consistent short-term benefits in individuals with type 2 diabetes mellitus (T2DM), particularly in improving neuropathy symptoms and functional performance [39–43]. Evidence from randomized controlled trials shows that whole-body vibration (WBV) significantly improves balance, reduces neuropathic pain, and enhances sensory perception in patients with diabetic peripheral neuropathy [31,44,45]. These findings are consistent with broader systematic and experimental literature demonstrating that vibration therapy enhances neuromuscular activation, proprioception, and postural control [7,46–48]. A key observation across studies is the more consistent improvement in neuropathy-related outcomes compared to perfusion and metabolic parameters [49–52]. Improvements in vibration perception threshold, plantar sensation, and pain

Figure 3, a summary plot showing the percentage distribution of risk of bias across domains. Most domains demonstrate predominantly low risk, with

reduction have been widely reported, suggesting enhanced peripheral nerve responsiveness and sensory integration [53–55].

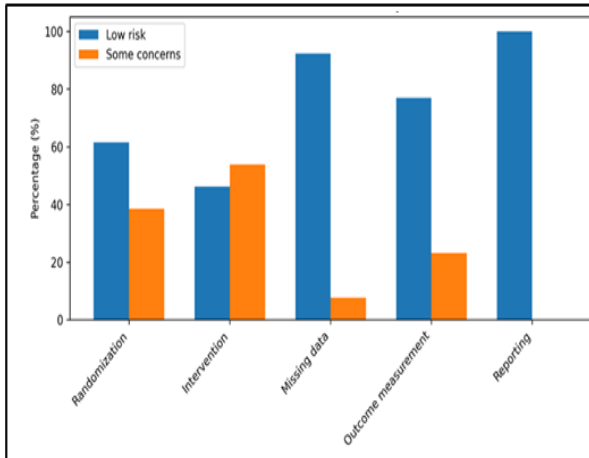


Figure 3: Risk of bias summary.

These effects are likely mediated by neuromechanical stimulation and stochastic resonance mechanisms, which amplify subthreshold sensory signals and improve afferent feedback [56–59]. In contrast, vascular responses such as improved microcirculation and tissue oxygenation are less consistent and appear to be influenced by intervention intensity, duration, and individual patient characteristics [60–63]. These findings suggest that vibration therapy primarily acts through neurosensory and neuromuscular mechanisms rather than sustained systemic metabolic changes [64–67]. The heterogeneity of intervention protocols represents a major limitation in the current evidence base. Studies vary widely in vibration frequency (typically 20–100 Hz), amplitude, session duration, and intervention length, making direct comparison challenging and limiting the development of standardized dosing guidelines [68–71]. Variations in frequency, amplitude, and treatment duration limit comparability across studies and hinder the development of standardized protocols [72–75]. Additionally, different modalities, including WBV platforms, focal muscle vibration, and wearable insole-based devices, introduce further variability, and the lack of head-to-head comparative trials prevents identification of the most effective intervention approach [23,76–79]. From a clinical perspective, improvements in balance and gait are particularly relevant, as individuals with diabetic peripheral neuropathy are at increased risk of falls and functional decline [9,15,80,81]. Enhanced postural stability and lower-limb strength may contribute to fall prevention strategies and improved quality of life [82–86]. However, there remains limited evidence demonstrating whether these functional improvements translate into long-term clinical outcomes such as reduced ulcer incidence, delayed disease progression, or decreased amputation rates [87–90]. However, there remains limited evidence demonstrating whether these functional improvements translate into long-term clinical outcomes [56,60,91–94]. Despite these limitations, vibration-based interventions offer several

advantages, including non-invasive application, ease of use, and feasibility for home-based care. These features support their integration into nursing-led management strategies for T2DM. Importantly, this review provides a novel contribution by integrating multiple vibration modalities across neuropathy, functional, and perfusion outcomes while identifying key gaps in standardization and long-term effectiveness. Furthermore, emerging evidence highlights the potential synergistic role of vibration-based therapies when combined with conventional rehabilitation and lifestyle interventions in individuals with T2DM [95–97]. Several studies have reported that integrating vibration therapy with structured exercise programs, balance training, or vascular interventions may enhance overall therapeutic outcomes, particularly in improving peripheral circulation, and neuromuscular coordination [30,98–100]. This combined approach may facilitate greater adherence and optimize physiological responses through multimodal stimulation pathways, including enhanced muscle activation, improved endothelial function, and augmented sensory feedback mechanisms. Additionally, wearable vibration devices offer promising opportunities for continuous or home-based therapy, which may support long-term health and reduce healthcare burden. Recent technological advancements, including smart insoles and adaptive vibration systems, further suggest a shift toward personalized and precision-based interventions tailored to patient-specific characteristics such as neuropathy severity and functional status.

Study Limitations

This review has several limitations. The included studies were heterogeneous regarding vibration frequency, intervention duration, and outcome measures. Most studies involved relatively small sample sizes and short follow-up periods, limiting the ability to assess long-term clinical outcomes. Additionally, the absence of meta-analysis precluded quantitative estimation of pooled effects.

Conclusion

In conclusion, wearable vibration-based interventions demonstrate promising short-term effectiveness in improving neuropathy symptoms and functional performance in individuals with type 2 diabetes mellitus, particularly in reducing pain, enhancing sensory function, and improving balance and gait. Although some evidence suggests potential benefits in perfusion and metabolic outcomes, these effects remain inconsistent and require further investigation. The overall strength of evidence is limited by small sample sizes, methodological variability, and short intervention durations, which restrict conclusions regarding long-term clinical impact. Future research should focus on large-scale randomized controlled trials with standardized protocols and clinically

meaningful outcomes to confirm long-term effectiveness and guide clinical implementation.

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Conflict of interests

The authors declare no conflict of interest.

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Data sharing statement

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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