Buerger-Allen Exercise for Improving Peripheral Perfusion and Wound Healing in Patients with Diabetic Foot: A Narrative Review

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Abstract. The shift of Type 2 Diabetes Mellitus (T2DM) toward younger demographics increases early-onset vascular complications such as diabetic foot ulcers. While standard clinical care enforces strict mechanical offloading, prolonged immobilization often impairs peripheral blood flow. Non-weight-bearing Buerger-Allen Exercise (BAE) offers a physiological pathway to restore lower-extremity circulation safely without compromising offloading principles. This narrative review aims to evaluate current clinical evidence regarding the role of BAE in improving peripheral perfusion and accelerating wound healing recovery. Literature was selected based on topical relevance, clinical evidence quality, and focus on recent publications. Synthesized clinical evidence demonstrates that structured BAE protocols consistently enhance lower extremity macro-perfusion, evidenced by increased Ankle-Brachial Index (ABI) values, alongside microcirculatory improvements in Capillary Refill Time (CRT) and skin temperature. Furthermore, BAE significantly improves objective wound healing scores and demonstrates synergistic efficacy when combined with standard foot or walking exercises. However, notable heterogeneity exists in current clinical guidelines and exercise dosing protocols. In conclusion, BAE serves as a safe, cost-effective, non-weight-bearing adjuvant nursing intervention that enhances lower-extremity perfusion and accelerates ulcer recovery, though standardized clinical guidelines remain urgently needed.

Keywords: Buerger-Allen Exercise, Type 2 Diabetes Mellitus, Diabetic Foot Ulcer, Peripheral Perfusion, Wound Healing.

1 Introduction

Type 2 diabetes mellitus (T2DM) poses a growing global non-communicable disease crisis, with its burden increasingly shifting toward younger and working-age populations across Asia, including Indonesia [1–4]. Chronic hyperglycemia accelerates the formation of advanced glycation end-products (AGEs), triggering oxidative stress and endothelial injury [5]. This vascular impairment predisposes patients to peripheral artery disease (PAD), characteristically affecting distal infra-popliteal vessels such as the dorsalis pedis and posterior tibial arteries, which compromises distal arterial inflow and clinically manifests as reduced ABI values and prolonged CRT [6].

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When this progressive vascular ischemia intersects with sensory nerve damage, the structural integrity of the lower extremity becomes severely compromised [5, 6]. Specifically, the convergence of diabetic peripheral neuropathy and local tissue ischemia creates a high-risk environment where unperceived mechanical trauma rapidly evolves into Wagner Grade 1 to 2 diabetic foot ulcers (DFU) [6, 7]. Conventional clinical management mandates strict offloading and non-weight-bearing immobilization to protect damaged tissue [7]. Paradoxically, prolonged physical inactivity induces muscular deconditioning and compromises lower-limb circulatory dynamics, which can delay wound healing [8]. Buerger Allen Exercise (BAE) offers a physiological alternative by utilizing postural elevation, dependency, and active ankle movements to stimulate endothelial shear stress and collateral perfusion without direct mechanical loading on the ulcerated foot [9].

However, existing literature remains fragmented, with most syntheses focusing solely on macrovascular parameters like ABI, while underreporting direct wound healing endpoints and exercise protocol dosing [10, 11]. Therefore, this narrative review aims to comprehensively analyze current clinical evidence regarding the effectiveness of BAE in improving lower-extremity perfusion parameters and accelerating wound recovery among T2DM patients presenting with DFU.

2 Method

This study employed a narrative review approach to identify, examine, and synthesize research findings relevant to the effectiveness of BAE in promoting wound healing and improving lower extremity perfusion among patients with diabetic foot or diabetic foot ulcer. The literature was selected based on its relevance to the research focus, with priority given to recent publications and studies of high methodological quality. Eligible studies were those with an original research design, an adequate sample size, and a low risk of significant bias.

The literature search was conducted using Semantic Scholar, PubMed, ScienceDirect, and Springer Nature, employing the following search keywords: ("Diabetic Foot" OR "Diabetic Foot Ulcer") AND ("BAE" OR "BAE"). The retrieved articles were subsequently reviewed using a narrative approach to provide a comprehensive overview of the topic.

3 Result and Discussion

The clinical evidence across the 12 selected research studies highlights the transformative potential of BAE as a non-invasive, cost-effective intervention for managing vascular complications in T2DM. From Indonesia, India, Egypt, to Pakistan, investigators consistently demonstrate that structured BAE protocols significantly bolster peripheral perfusion by improving the ABI, reducing CRT, and elevating distal skin temperature. The comprehensive baseline characteristics and extracted parameters of the 12 included studies are systematically summarized in Table 2. By utilizing gravitational shifts and muscle pump activation through its structured three-stage protocol consisting of elevation, dependency, and horizontal rest, BAE effectively promotes collateral circulation and enhances tissue oxygenation.

Findings across diverse patient cohorts, including elderly populations and individuals presenting with chronic neuropathic ulcers, suggest that BAE is not only superior to conventional methods such as ankle pumping or standard foot exercises but also achieves distinct synergistic results when paired with walking or concurrent physical therapies. Ultimately, this synthesis confirms that BAE serves as a practical, nurse-led solution capable of bridging the gap in diabetic care, successfully migrating patients from high-risk circulatory insufficiency categories into normal physiological ranges to prevent debilitating outcomes.

3.1 Pathophysiology of Diabetic Foot

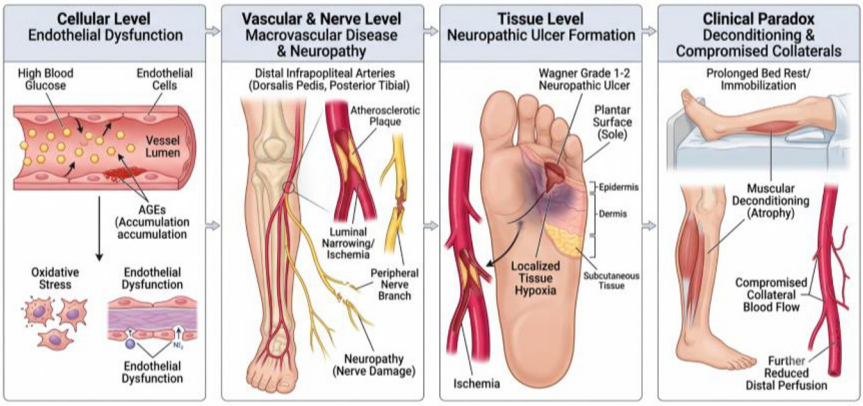


Fig. 1. Sequential pathophysiology of DFU formation (illustrated by authors).

The development of diabetic foot complications in patients with T2DM is driven by a complex pathophysiological cascade initiated by chronic hyperglycemia [5]. Persistent elevation of circulating blood glucose accelerates the intracellular accumulation of AGEs [5]. This metabolic alteration induces continuous oxidative stress, systemic inflammation, and severe endothelial cell dysfunction [5]. Over time, this endothelial injury leads to progressive PAD, characteristically affecting distal infra-popliteal vessels such as the dorsalis pedis and posterior tibial arteries (Fig. 1) [6]. At the tissue level, impaired macrovascular and microvascular integrity causes severe blood flow restriction, directly reflected in significant reductions of the ABI and prolonged CRT [6].

This state of chronic tissue hypoxia and localized ischemia frequently intersects with diabetic peripheral neuropathy [6]. The loss of protective sensation prevents patients from feeling minor mechanical trauma or focal pressure, allowing unnoticed skin breakdown to rapidly evolve into Wagner Grade 1 to 2 DFU [6, 7]. To protect the ulcerated tissue from mechanical shear stress, standard clinical guidelines mandate strict offloading and non-weight-bearing immobilization [7]. Paradoxically, prolonged physical inactivity and prolonged bed rest cause muscular deconditioning and further compromise lower-limb circulatory dynamics [8]. This creates a detrimental feedback loop that exacerbates local tissue hypoxia and delays wound healing, highlighting the clear physiological rationale for non-weight-bearing physical interventions like BAE [7, 8].

3.2 Mechanism of BAE

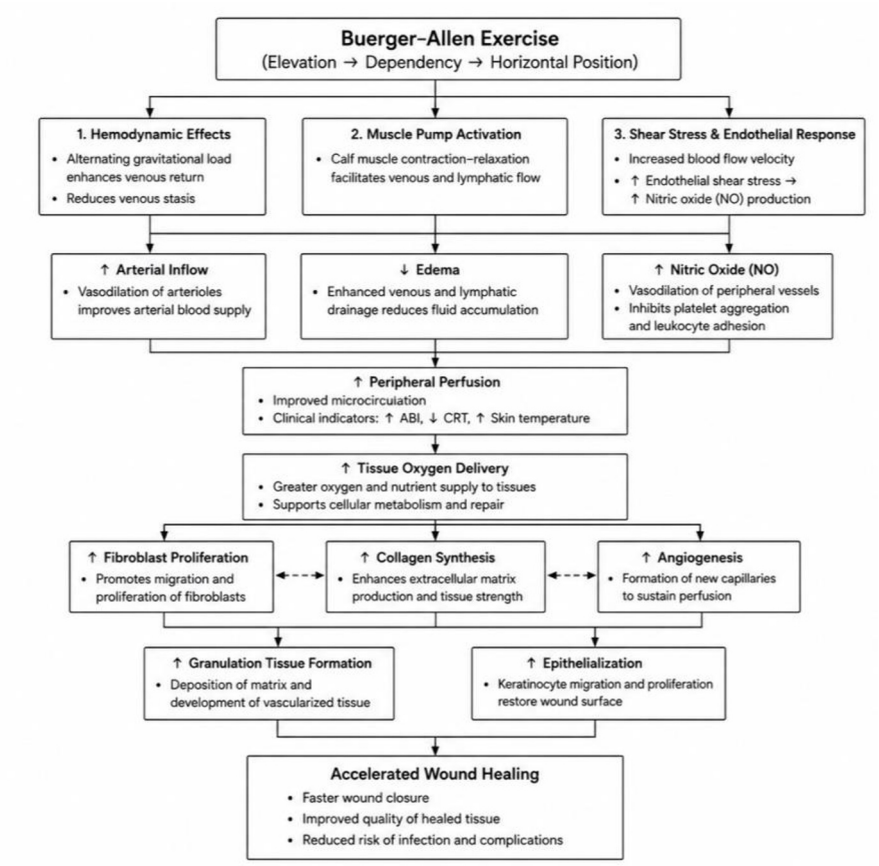


Fig. 2. Mind Map of BAE. [12]

BAE may improve lower-extremity perfusion through several complementary physiological mechanisms (Fig. 2) [9]. The alternating elevation, dependency, and horizontal positions produce changes in gravitational pressure that facilitate venous return and reduce venous stasis [9]. In addition, activation of the calf muscle pump supports venous and lymphatic drainage, which may help reduce lower-limb edema [9]. Repeated changes in limb position and increased blood flow may also increase endothelial shear stress, stimulating nitric oxide (NO) production and promoting peripheral vasodilation [6, 9]. These combined effects can enhance arterial inflow and microcirculation, resulting in improved peripheral perfusion, which may be reflected by an increased ABI, shorter CRT, and increased skin temperature [6, 10].

Improved peripheral perfusion may subsequently increase tissue oxygen delivery, providing adequate oxygen and nutrients to support cellular processes involved in wound repair [9, 11]. Increased oxygen availability can promote fibroblast proliferation and collagen synthesis, which are essential for extracellular matrix formation and tissue strength [9]. At the same time, angiogenesis contributes to the formation of new capillaries and supports continued oxygen and nutrient delivery to the healing tissue [6, 9]. These processes facilitate granulation tissue formation and

epithelialization through the development of new tissue and restoration of the wound surface [9, 11]. Therefore, BAE may contribute to accelerated wound healing through a sequential pathway involving improved circulation, enhanced tissue oxygenation, increased cellular activity, and tissue regeneration [9, 11].

3.3 Clinical Evidence

The synthesized clinical evidence across the included studies demonstrates that BAE significantly enhances lower-extremity macrovascular perfusion in patients with T2DM [13, 15–24]. Post-intervention ABI values consistently showed statistically significant improvements, with net gains ranging from +0.05 to +0.34 across diverse clinical settings [13, 15–24]. Studies evaluating acute or short-term protocols (spanning from a single 20-minute session to 3–6 days) reported meaningful transitions from baseline arterial obstruction (ABI 0.65–0.85) to physiological normal ranges (≥0.90) [18, 20, 23, 24]. Furthermore, comparative trials revealed that BAE provides superior hemodynamic benefits over conventional foot exercises or isolated ankle pumping [17, 21], with the highest ABI enhancements observed when BAE was combined with diabetic foot exercises or structured walking programs [16, 22].

In addition to macrovascular gains, BAE yields profound microcirculatory improvements and accelerates localized wound recovery [13, 14, 18, 23]. Multi-week interventions significantly improved microvascular markers, reducing CRT from abnormal delays (>3 seconds) to normal physiological levels (<2 seconds) in up to 80% of treated patients [13, 18, 23], alongside an average distal skin temperature elevation of +1.1°C [18]. At the tissue level, empirical data from randomized controlled trials confirm that these vascular enhancements directly translate into active tissue repair [14]. Patients with Wagner Grade 1 to 2 neuropathic ulcers receiving adjuvant BAE demonstrated a marked increase in objective wound healing scores (+6.65, $p < 0.05$) [14], driven by postural shear stress and enhanced local oxygen delivery. The chronological trajectory and thematic evolution of clinical evidence regarding BAE from 2024 to 2026 are visually summarized in Figure 3 (Fig. 3) and detailed in Table 2 [13-24].

Table 1. Data Synthesis.

Author/ Year/Title	Country	Study Design	n Sample (Study/Control)	Sample & Method	Key Findings	Result
Ahmed, M. K. *et al* (2025). Effect of Buerger Allen exercise on improving lower extremities perfusion among diabetic elderly patients: Randomized clinical trial	Egypt	Quasi-experimental	120 (60/60)	Elderly diabetics (60+) at Minia University Hospital. Intervention: Buerger Allen Exercise 5-6 times/day (12-15 mins) for 8 weeks.	65% of the study group showed good peripheral perfusion post-test vs 43.3% pre-test. Improved pulses and capillary refill.	The combination of BAE and diabetic foot exercises yielded the highest increase in ABI values (+0.308) compared to performing either exercise individually (p=0.001)
Lal, S. & Kumar, R.A. (2025). Effectiveness of Buerger Allen Exercise on Lower Limb Tissue Perfusion Among Patients with Diabetes Mellitus: A Quasi-Experimental Study	India	Quasi-experimental	60 (30/30)	Diabetic patients with ABI < 0.9. Intervention: BAE twice daily for 20 minutes over 4 weeks vs. routine care.	Significant improvements in ABI, capillary refill time, and skin temperature in the experimental group.	The BAE group showed significant improvements in ABI (+0.12), CRT reduction (-1.1 seconds), and skin temperature increase (+1.1 °C) after 4 weeks (p<0.05)
Rani, *et al* (2026). The Effect of Buerger Allen Exercise and Walking Exercise on Ankle Brachial Index among Patients with Type-2 Diabetes Mellitus	India	Quasi-experimental	60 (30/30)	Patients with Type 2 DM. Intervention: BAE and walking exercise for 2 weeks. Measurement: Digital sphygmomanometer.	Significant increase in average ABI value in the intervention group from 0.748 (pre-test) to 0.812 (post-test).	The combination of BAE and walking exercises significantly improved peripheral circulation and increased ABI scores compared to the control group (0.812 vs. 0.739; p=0.041)
Jannah, R., *et al* (2024). Differences in The Effectiveness	Indonesia	Quasi-experimental	30 (15/15)	T2DM patients in Patrang. Comparison: BAE vs.	BAE is more effective than Foot Exercise in	BAE was more effective in improving peripheral perfusion (mean ABI 0.992)

Author/ Year/Title	Country	Study Design	n Sample (Study/Control)	Sample & Method	Key Findings	Result
of Buerger Allen Exercise and Foot Exercises on Peripheral Perfusion				Diabetic Foot Exercise for 20 mins; measured by ABI.	increasing ABI (BAE average 0.992 vs Foot Exercise 0.900).	compared to standard foot exercises (mean ABI 0.900) with a p-value of 0.004
Abbas *et al.* (2024). Effect of BAE and Intraneural Facilitation on Lower Extremity Perfusion	Pakistan	Quasi-experimental	12 (6/6)	Type II DM patients with neuropathy. Comparison: BAE (postural changes) vs. Intraneural Facilitation (manual therapy) for 3 months.	Both groups significantly improved ABI and MNSI scores. BAE showed higher patient compliance.	Both BAE and Intraneural Facilitation effectively increased ABI and reduced neuropathy symptoms; however, BAE showed better patient compliance and ease of use
Ajith M., *et al* (2025). Assess the Effects of BAE on the Healing of Neuropathic Diabetic Foot Ulcers	India	RCT	60 (30/30)	Type 2 DM with neuropathic foot ulcers. Intervention: BAE (elevation, dependent, horizontal positions) vs. routine care.	The experimental group showed significant improvement in wound healing scores (22.37 to 29.02).	BAE significantly accelerated the healing of neuropathic diabetic foot ulcers, showing a mean difference score of 6.65 ($p<0.05$) compared to the control group
Widiastuti, *et al* (2024). BAEs' effectiveness for improving lower limb circulation	Indonesia	Quasi-experimental	24 (12/12)	Patients with Type 2 DM. Intervention: BAE for 21 mins/session for 6 days vs. education control.	Significant difference in circulation (ABI) before and after intervention in the BAE group only.	BAE effectively improved lower limb circulation (ABI increased by 0.25), significantly reduced blood glucose levels, and enhanced leg sensitivity ($p=0.000$)
Putri, *et al* (2026). Efektivitas Ankle Pumping Exercise dan	Indonesia	Quasi-experimental	26 (13/13)	T2DM patients without ulcers. Comparison: Ankle	Both exercises improved ABI and sensitivity, but	BAE proved superior to ankle pumping exercises in increasing both Ankle-

Author/ Year/Title	Country	Study Design	n Sample (Study/Control)	Sample & Method	Key Findings	Result
Buerger Allen Exercise terhadap Sirkulasi				Pumping Exercise vs. Buerger Allen Exercise.	Buerger Allen Exercise was significantly more effective.	Brachial Index (ABI) values (1.116 vs. 1.020) and foot sensitivity (p=0.018 and 0.009)
Permatasari *et al*. (2025). Impact of Buerger Allen Exercise on Ankle Brachial Index in Type II Diabetes Mellitus Patients	Indonesia	Pre-experimental	40 (20/20)	Elderly patients with T2DM. Intervention: One 20-minute session of Buerger Allen Exercise.	BAE improved ABI values; treatment group mean 0.79 vs. control group 0.69.	A single 20-minute BAE session produced a significant impact on ABI values (0.79 in the intervention group vs. 0.69 in the control group) with a p-value of 0.003
Heriyanto *et al* (2024). Efek Kombinasi Terapi Buerger Allen Exercise dan Senam Kaki Diabetes terhadap Ankle Brachial Index Penderita Diabetes	Indonesia	Quasi-experimental	57 (19 combined BAE + foot exercise/19 BAE only/ 19 Foot exercise only)	Diabetic patients. Intervention: Combined BAE and foot exercises (10 mins each) for 5 days.	Significant increase in ABI values in the intervention group (mean 0.8195) compared to control.	The combination of BAE and diabetic foot exercises yielded the highest increase in ABI values (+0.308) compared to performing either exercise individually (p=0.001)
Anggraini & Wijaya (2024). Pengaruh Terapi BAE Terhadap Nilai ABI Pada Penderita Diabetes Mellitus Tipe 2	Indonesia	Quasi-experimental	15	Patients with Type 2 DM. Intervention: BAE therapy with pre- and post-test ABI measurements.	Mean ABI increased from 0.84 to 0.96. 93.3% of respondents reached normal ABI levels.	BAE therapy significantly increased the mean ABI value from 0.84 (mild obstruction) to 0.96 (normal) with a p-value of 0.000
Thakur (2025). Effectiveness of BAEs in Improving Lower	India	RCT	60 (30/30)	Hospitalized T2DM patients with ABI < 1. Intervention:	Significant mean ABI improvement (1.20) vs. control (0.94). Improved	A 3-day BAE intervention significantly improved ABI values (1.20 vs. 0.94) and

Author/ Year/Title	Country	Study Design	n Sample (Study/Control)	Sample & Method	Key Findings	Result
Extremity Perfusion: A Randomized Controlled Trial				BAE 3x daily for 3 days vs. control.	pulses and skin temperature.	normalized capillary refill time (CRT) and skin temperature ($p<0.05$)

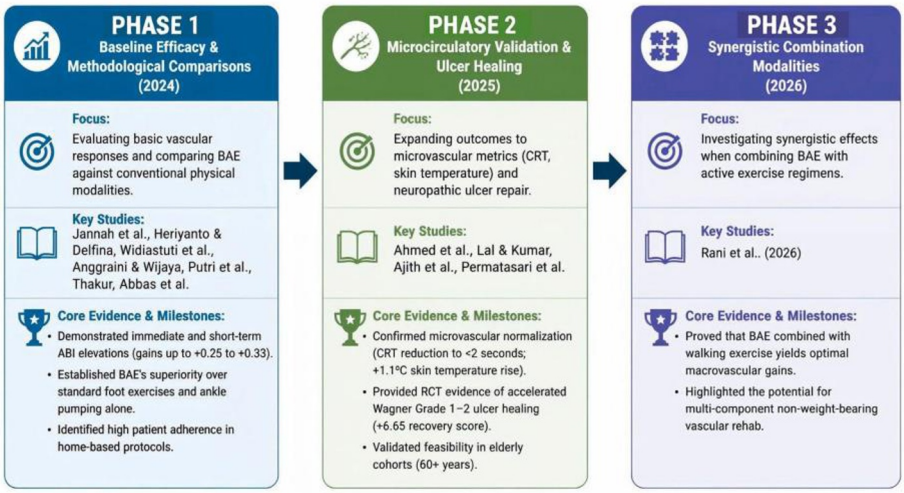


Fig. 3. Chronological development and progression of BAE research (2024–2026) (synthesized by authors).

3.4 Current Guidelines

Current international clinical practice guidelines for DFU management, such as the International Working Group on the Diabetic Foot (IWGDF) 2023 update, establish mechanical offloading, infection control, local wound debridement, and glycemic optimization as the core standard of care. These guidelines mandate strict offloading to protect active lesions from mechanical trauma and shear stress. However, non-weight-bearing physical interventions aimed at actively restoring lower-extremity vascular blood flow, such as BAE, are currently not included in formal first-line clinical algorithms. Consequently, BAE functions as a complementary or adjuvant nursing therapy designed to enhance regional perfusion without compromising the essential non-weight-bearing principles required by standard offloading guidelines.

In addition to its absence from primary guidelines, an analysis of the existing literature reveals a notable lack of clinical standardization regarding BAE intervention protocols. Although all included studies adhere to the historical three-stage sequence of leg elevation, dependency, and horizontal rest, their operational parameters vary significantly. Prescribed exercise frequencies range from single 20-minute sessions to intensive regimens repeated 5 to 6 times daily, with study durations spanning from acute 3-to-6-day hospital protocols to longitudinal 8-week programs. This operational heterogeneity underscores the need to develop standardized, evidence-based clinical practice guidelines that clearly specify optimal session frequency, phase duration, and overall treatment length for patients with T2DM.

3.5 Clinical Implications

These findings have broad clinical implications for a wide range of health professions. Nurses can integrate BAE as a self-contained nursing intervention that is easy to teach and supervise during hospital and community care, and make it part of routine health education for T2DM patients. Physiotherapists can incorporate BAE into vascular rehabilitation programs to improve peripheral circulation and lower limb function. Physicians may recommend BAE as a safe and inexpensive non-pharmacological adjuvant therapy to complement pharmacological treatment and prevent progression of vascular complications. Researchers are encouraged to conduct further studies with large-scale RCT design, long follow-up duration, and exploration of additional objective parameters such as transcutaneous oxygen pressure ($TcPO_2$) measurement to strengthen scientific evidence. In addition, public health workers and health cadres can train patients and families to conduct BAE independently at home, so as to reach the population in areas with limited access to health services. Overall, this cross-professional collaboration is very important to optimize the implementation of BAE in the management of T2DM in a holistic and sustainable manner.

3.6 Research Gap

Despite the growing evidence supporting the benefits of BAE for diabetic foot management, a critical synthesis of the current literature reveals several key research gaps. Methodologically, many studies rely on small sample sizes, ranging from 12 to 30 participants, and non-randomized or quasi-experimental designs, which limits statistical power and increases the risk of study bias. Furthermore, intervention protocols vary widely and often lack clear reporting on specific exercise dosing, frequency, or duration. Most trials evaluate short-term outcomes, spanning from a single 20-minute session to brief multi-day programs, without including long-term follow-up to assess the lasting vascular benefits or ulcer recurrence rates. Another notable gap lies in the clinical parameters evaluated and the demographics studied. Most research focuses predominantly on macrovascular markers like the ABI, while microcirculatory measures such as CRT, skin temperature, and direct wound healing scores remain underreported. Additionally, existing studies heavily center on older adult populations or patients without active foot ulcers. This creates a clear need for future trials to investigate BAE efficacy across broader patient groups, particularly younger adults with early-onset T2DM and active neuropathic ulcers.

3.7 Future Perspective

In the future, BAE research requires further development with large-scale and multicenter RCT design, long follow-up duration, and additional objective parameters such as $TcPO_2$ or SPP to strengthen evidence. The utilization of digital technology such as BAE guidance applications can improve patient compliance. Comparative research with other therapies is also important to strengthen BAE's position in clinical guidelines. Thus, BAE has the potential to become a standard intervention integrated in the management of T2DM nationally and internationally.

4 Conclusion and Recommendation

Based on the synthesis of 12 analyzed studies, BAE effectively enhances lower extremity perfusion in T2DM patients, as evidenced by increased ABI values, accelerated CRT, and elevated skin temperature [13, 17, 18]. Combining gravitational postural shifts with muscle pump activation via active ankle movements, BAE demonstrates superior efficacy compared to conventional foot or ankle pumping exercises, both independently and synergistically with walking regimens [16, 17, 21]. Furthermore, randomized controlled trial evidence confirms that BAE improves macro- and microvascular hemodynamic parameters while significantly accelerating Wagner Grade 1–2 neuropathic diabetic foot ulcer healing, yielding clinically meaningful improvements in objective wound recovery scores [14].

Consequently, BAE represents a promising, non-invasive intervention for improving lower-extremity perfusion and wound healing in patients with T2DM . However, the methodological limitations identified in this review particularly small sample sizes and inconsistent intervention protocols highlight the need for future research to move beyond preliminary quasi-experimental designs. Large-scale, multicenter randomized controlled trials with standardized BAE protocols and extended follow-up periods are essential to confirm its long-term clinical effectiveness, particularly regarding ulcer recurrence and sustained perfusion outcomes. Future studies should also expand the scope of measured parameters beyond ABI to include microcirculatory markers and objective wound healing indices, while incorporating more diverse populations particularly younger adults with active neuropathic ulcers to strengthen the generalizability of findings.

5 Limitations

Despite these promising results, this review has several limitations. Most of the included studies employed quasi-experimental designs with relatively small sample sizes (12–60 participants), which reduces statistical power and increases the risk of bias. Intervention durations and dosing protocols also varied considerably across studies, ranging from a single 20-minute session to an 8-week program, without clear standardization of session frequency, phase duration, or overall treatment length. In addition, the majority of studies focused primarily on macrovascular parameters (ABI),

while data on microcirculatory markers (CRT, skin temperature) and direct wound healing outcomes remain limited. The study populations were also predominantly older adults or patients without active ulcers, which limits the generalizability of findings to younger adults with active neuropathic ulcers.

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Disclosure of Interests. None declared.

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