

REVIEW ARTICLE:

Effect of Exercises on Foot Posture, Balance and Functional Performance in patients with Type 2 diabetes: A Systematic Review

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ABSTRACT

Introduction: T2DM is a major public health concern. Exercise interventions have been widely recognized as a cornerstone in the management of T2DM with evidence showing improvement in glycemic control, health related cardiovascular system and overall physical functional performance. However, the specific effects of exercise on foot posture, balance, and functional performance in patients with T2DM remain less explored. This systematic review aims to synthesize existing evidence on the impact of exercise interventions on foot posture, balance, and functional performance in individuals with T2DM, providing insights into the efficacy of such interventions and guiding future clinical practice. **Methodology:** This systematic review was conducted according to the PRISMA guidelines. Various databases were used to search relevant articles using different keywords. Study was registered in PROSPERO (CRD420251004178). Pedro was done to assess the quality of selected article. **Result:** 1642 articles were selected for reviewing. After 1st screening, 1002 articles were removed due to duplication. On the basis of eligibility criteria, 693 articles were removed after the 2nd screening. On the basis of eligibility criteria only 7 articles were selected for review. Once all of the articles were screened as per eligibility standard, a final batch of articles was chosen. **Conclusion:** In conclusion, the reviewed evidence supports the use of structured exercise interventions in improving balance, posture and strength which improves overall functional performance in individuals with diabetic patients.

Keywords: Exercises, Foot Posture, Balance, Functional Performance, T2DM

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Introduction

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance and hyperglycemia, often leading to various complications such as peripheral neuropathy, musculoskeletal impairments, and altered foot biomechanics. These complications may result in poor foot posture, reduced balance, and diminished functional performance, significantly impacting patients' quality of life and increasing the risk of falls and mobility-related disabilities¹.

Globally, T2DM is a major public health concern, affecting approximately 537 million adults (20–79 years) in 2021, with projections indicating an increase to 643 million by 2030 and 783 million by 2045. It accounts for over 90% of all diabetes cases worldwide, with an estimated global prevalence of 10.5% in 2021². The World Health Organization (WHO) recognizes diabetes as a leading cause of morbidity and mortality, particularly impacting low- and middle-income countries³. India often referred to as the "diabetes capital of the world," is among the most affected nations. As of 2021, 74 million adults in India had diabetes, making it the second-highest globally after China. The prevalence rate among adults was 9.6%, with numbers expected to rise to 124 million by 2045 if preventive measures are not effectively implemented. Alarming, nearly 57% of diabetes cases in India remain undiagnosed, highlighting the urgent need for increased awareness, early diagnosis, and intervention strategies^{2,3}.

Foot posture is defined as the alignment and positioning of the foot during static and dynamic activities which is often compromised in T2DM due to structural and muscular changes such as arch collapse, joint stiffness or muscle weakness⁴. T2DM may contribute to the reduction of the sensory pathway which may impact the regulation of the motor and postural control system². Therefore, balance is another common stemming from sensory and motor impairments. Thus, individuals with peripheral neuropathy are more likely to suffer from episodes of falls and also have difficulty in performing ADLs and walking on different pathways⁵, affecting the functional performance which is frequently hindered by reduced strength, flexibility, and coordination⁵. Evidence shows that individual with T2DM have at least minimum 1 functional disability and found it difficult to walk for at least 400⁶.

Exercise interventions have been widely recognized as a cornerstone in the management of T2DM, with evidence showing improvement in glycemic control, health related cardiovascular system and overall physical functional performance⁷. However, the specific effects of exercise on foot posture, balance, and functional performance in patients with T2DM remain less explored. Understanding these effects is crucial, as targeted exercise programs may offer a non-pharmacological approach to mitigating diabetes-related complications and enhancing mobility. This systematic review aims to synthesize existing evidence on the impact of exercise interventions on foot posture, balance, and functional performance in individuals with T2DM, providing insights into the efficacy of such interventions and guiding future clinical practice.

Methodology

Protocol and Registration: This systematic review was conducted according to the PRISMA guidelines⁸. Various databases were used to search relevant articles using different keywords. All of the articles were gathered, and with the help of Zotero, duplicates were removed. Once all of the articles were screened as per eligibility standard, a final batch of articles was chosen. Inclusion criteria where all articles should be in English language, article study design should be RCT, participants included in the study were of both gender, above 18 years old and diagnosed with T2DM, Articles should have included at least one outcome (balance, foot posture, functional performance). Exclusion criteria were non-English article, articles from conference proceeding, thesis or incomplete article. The systematic review was registered in PROSPERO international prospective register of systematic reviews. (CRD420251004178).

Data Source & Search Strategy: We searched the electronic databases of PubMed, Scopus and Google Scholar. According to the Cochrane Handbook for Systematic Review of Interventions⁹, the search strategy was divided into two, i.e. intervention and condition. The search strategy included different combinations of keywords: Exercises AND Foot Posture AND Diabetes or T2DM, Exercises AND Balance AND Diabetes or T2DM, Exercises AND Functional Performance AND Diabetes or T2DM, Exercises AND Foot Posture OR Balance OR Functional Performance AND Diabetes or T2DM, RCT OR Randomized Controlled Trial. Search scale as kept between the span of 2019-205.

Study Selection: For the purpose of this review, we only included English language RCTs that met the following criteria: participants with T2DM, from 18 years and above age group and of both gender. We included trials that broadly evaluated foot posture, balance and functional performance. Articles were excluded if they were unpublished articles or research abstract from a meeting proceeding, PhD thesis or in different language. Two reviewers independently screened the titles and abstracts to identify potentially eligible articles. The complete manuscripts were then independently reviewed to identify studies that met all the inclusion criteria. Disagreements were resolved by discussion among authors. The PICOS question was then chosen as follows: **P** – population: T2DM patients; **I** – intervention: Exercises as Physiotherapy Approach; **C** – control: different intervention or no treatment is given; **O** – outcome measure: Posture, balance and functionality; **S** – study designs: experimental studies (RCT).

Quality Assessment: All data was extracted and entered into a standard data extraction sheet for analysis. Quality assessment of each included trial was done via PEDro Scale. The PEDro scale scores range from 0 to 10, calculated from the total number of criteria met for items, higher scores indicating better methodological quality⁹.

Result

Study Selection: The selections of studies were shown in flowchart (Fig. 1). Initially 1642 articles were selected for reviewing. After 1st screening, 1002 articles were removed due to duplication. On the basis of eligibility criteria, 693 articles were removed after the 2nd screening phase that is abstract analysis: 262, 284 were not related to Diabetes or related complications, 59 were removed as articles were from conference proceeding, language other than English or full text was not available, and 35 articles were not RCTs. On the basis of eligibility criteria only 7 articles were selected for review (Figure-1).

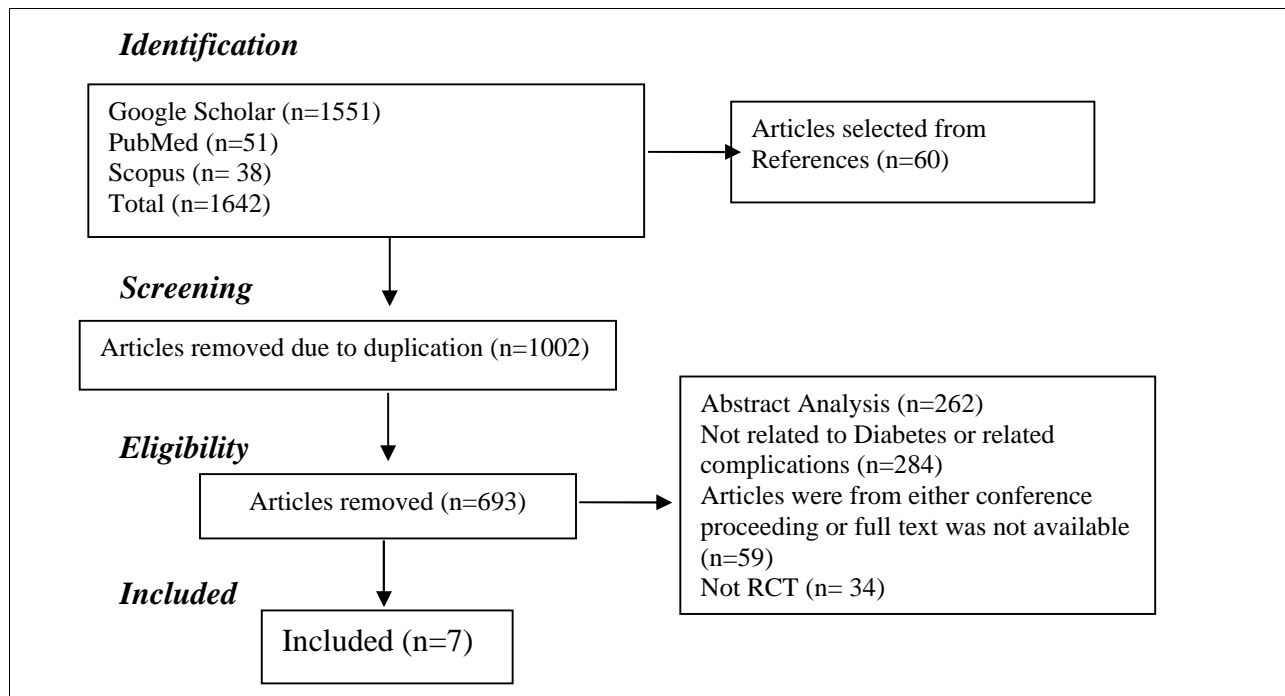


Figure 1: PRISMA Flowchart

Study Characteristics: Studies characteristics such population, intervention, outcome measures and result are discussed in table 1.

Table-1: Study characteristics of the included studies

Author, Year	Population	Intervention	Outcome Measures	Results
Venkataraman K et al (2019) ¹¹	143 Individuals with diabetic peripheral neuropathy	Experimental group: Short-term strength and balance training; Control group: No specific training	Ankle muscle strength SF-36; TUG test performance; Knee ROM; Balance confidence score	Improved functional status but no significant change in quality of life
Borges Pletsch A et al (2021) ¹²	80 People with diabetes	Experimental group: Proprioceptive training either at home or under supervision; Control group: No training	Bipedal balance Test Gait, Balance, Evaluation Systems Test (BES Test)	Improved postural control in supervised and home-based groups compared to control
Monteiro RL et al (2022) ¹³	78 People with diabetic neuropathy	Experimental group: Foot-ankle therapeutic exercises focusing on strength, mobility, and proprioception; Control group: Standard care without exercise intervention	Foot Health Status Questionnaire, Hallux & toe muscle strength; EQ-5D questionnaire	Significant improvement in gait speed in the experimental group
Al Ozairi E et al, (2023) ¹⁶	30 People with type 2 diabetes	Experimental group: Home-based resistance exercise training with progressive load adjustments; Control group: No exercise intervention	Upper limb Strength glucose control	Improved strength and glucose control in the experimental group

Cruvinel-Júnior RH et al, (2024) ¹⁹	62 People with diabetic foot risk	Experimental group: Web-based foot-ankle exercise program; Control group: Standard diabetic foot care	EQ-5D-3L Questionnaire Foot Health Status Questionnaire, Foot pain, Foot function score	Effective foot care and cost-efficient intervention
Gupta G et al (2025) ¹⁵	120 Elders with diabetic neuropathy	Experimental group: Multifactorial balance rehabilitation with strength, coordination, and proprioception exercises; Control group: Routine diabetic care	Dynamic Balance Upper and lower limb strength and flexibility	Improved balance and reduced fall risk in the experimental group

Population: The total number of participants included in the randomized controlled trials (RCTs) was 433 (143, 78, 30, 62, and 120). The reported mean age of participants varied across studies, ranging from 18 to 71.2 years, with specific values of 35–50 years, 61.5 years, 71.2 years, 18–65 years, and 60.2 years ¹⁰⁻¹⁵.

Outcome Measures: The included studies utilized various outcome measures, including the EQ-5D-3L Questionnaire to assess health-related quality of life and the Foot Health Status Questionnaire to evaluate foot-related pain and function. Foot pain and Foot function score were specifically analyzed to determine the impact on mobility. Dynamic balance was measured alongside bipedal balance test and the Balance Evaluation Systems Test (BESTest) to assess postural stability. Additionally, upper and lower limb strength and flexibility to evaluate musculoskeletal performance. Glucose control was considered as a metabolic outcome, while gait parameters were assessed to determine locomotor function. TUG test performance to measure functional mobility. Knee ROM was evaluated to determine joint flexibility, while the balance confidence score provided insights into individuals’ self-perceived stability¹⁰⁻¹⁵.

Quality Assessment of Study: Quality assessment of study was done via PEDro Scale. All three studies are considered as highly ‘good’ to ‘excellent’ studies as scores of the studies range between 6-8/10 and 10/10. Scoring of these studies was summarized in Table 2.

Table-2: Pedro Scoring

Study	Eligibility criteria’s were specified (1-11)										Total	
										0		1
Venkataraman K et al ¹⁰	1	1	1	1	0	0	1	1	1	1	1	
Borges Pletsch A et al ¹¹ .	1	1	0	1	0	0	0	1	1	1	1	6/10
Monteiro RL et al ¹² .	1	1	1	1	0	0	1	1	1	1	1	7/10
Al Ozairi E et al ¹³	1	1	1	1	1	0	1	1	1	1	1	8/10
Cruvinel-Jr RH et al ¹⁴ .	1	1	1	1	0	0	1	1	1	1	1	7/10
Gupta G et al ¹⁵ .	1	1	0	1	0	0	0	1	1	1	1	6/10

Outcome Measures: The included studies focused upon Functional status, quality of life, Balance, Gait Speed, Foot function, economic evaluation, fall risk, Strength and glucose control. Outcome differences were observed in the studies but our study has focused on inclusion outcome of this study, thus measurement of other outcomes is one the limitation. Discussed in table 1.

Discussion

The available randomized controlled trials (RCTs) indicate that exercise-based interventions significantly enhance balance, strength, and functional status in individuals with diabetic neuropathy (DPN). The findings support the effectiveness of foot-ankle strengthening, proprioceptive training, resistance exercise, and web-based rehabilitation programs, showing improvements in gait speed, postural control, muscle strength, and fall risk reduction. However, despite these benefits, certain studies did not report significant quality of life improvements, suggesting that multidimensional interventions may be necessary for long-term functional gains.

Several studies have emphasized the role of foot-ankle exercises and proprioceptive training in enhancing gait speed and postural control. Monteiro et al (2022)¹³ found that a foot-ankle strengthening program significantly improved gait speed, demonstrating that targeted lower limb neuromuscular activation can enhance motor control and mobility in DPN patients.

Similarly, Borges Pletsch et al (2021)¹² reported that proprioceptive training, whether performed at home or under supervision, improved postural control. These findings align with Topp et al. (2018),¹⁴ who reported that progressive balance training led to enhanced functional mobility and reduced postural sway in DPN patients. Additionally, Gupta et al (2025)¹⁵ demonstrated that a multifactorial balance rehabilitation program, incorporating strength, coordination, and proprioception exercises, significantly reduced fall risk among elderly individuals.

The role of resistance training in muscle strength and metabolic health is also well-documented. Al Ozairi et al (2023)¹⁶ found that home-based resistance training significantly improved muscle strength and glucose control in individuals with type 2 diabetes, reinforcing the metabolic benefits of resistance exercises.

These findings are consistent with Colberg et al (2016)¹⁷, who emphasized that structured resistance training enhances insulin sensitivity, improves muscle function, and reduces the risk of diabetic complications. However, Venkataraman et al (2019)¹¹ reported that while short-term strength and balance training improved functional status, it did not significantly affect quality of life. This aligns with Kruse et al (2019)¹⁸, who found that while exercise interventions improved neuromuscular function, they had limited impact on psychological well-being, highlighting the need for long-term adherence and psychological support in rehabilitation programs.

A notable innovation in exercise interventions is the integration of digital rehabilitation programs. Cruvinel-Júnior et al (2024)¹⁹ demonstrated that a web-based foot-ankle exercise program was both effective and cost-efficient in improving foot function and diabetic foot care, reinforcing the potential of tele-rehabilitation in managing diabetic complications. This aligns with Petrofsky et al (2020)²⁰, who reported that mobile-based exercise interventions improved neuromuscular function, pain management, and adherence rates in DPN patients. Given the increasing shift toward telemedicine and digital health solutions, web-based interventions could provide scalable, accessible, and long-term solutions for diabetic neuropathy rehabilitation. Similarly, Petrofsky et al (2020)²⁰ found that mobile-based exercise interventions improved adherence rates, pain management, and neuromuscular function in diabetic patients. These findings suggest that digital rehabilitation platforms could enhance accessibility and patient engagement, particularly in low-resource settings.

The use of whole-body vibration therapy (WBVT) as an intervention has also been explored. Del Pozo-Cruz et al (2013)²¹ conducted a 12-week WBVT trial and found significant balance improvements in individuals with type 2 diabetes. The study suggests that mechanically-induced neuromuscular stimulation may be an effective adjunct therapy for improving postural stability in patients with diabetic neuropathy. These findings are similar to, Topp et al (2018)¹⁴, who reported that progressive balance training led to enhanced functional mobility and reduced postural sway in DPN patients. However, further research is needed to determine the long-term sustainability of these gains.

Limitation: Despite these promising outcomes, some limitations remain. Most studies focused on short-term effects, leaving questions about long-term adherence and sustainability of functional gains. Additionally, while balance and strength training significantly improved neuromuscular control, their real-world application in fall prevention and daily mobility remains under explored. Future research should emphasize longitudinal follow-ups, hybrid rehabilitation models (supervised + home-based training), and psychological well-being assessments to develop comprehensive rehabilitation strategies.

Conclusion

In conclusion, the reviewed evidence supports the use of structured exercise interventions in improving balance, posture and strength which improves overall functional performance in individuals with diabetic patients. However, for sustained functional gains, integrating long-term adherence strategies, digital rehabilitation, and psychological support into rehabilitation programs may be necessary.

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