REVIEW ARTICLE

Effectiveness of Functional Balance Exercises on Dynamic Balance in Individuals with Diabetic Peripheral Neuropathy: A Systematic Review and Meta-Analysis

Unaiza Abdul Hameed[1], Prof. Syed Abid Mehdi Kazmi[2], Dr. Fasiha Sohail[3]

Assistant Manager, Dr. Ziauddin University Hospital, Clifton[1], Group Head, Rehabilitation Sciences, Dr. Ziauddin University Hospital[2], Associate Professor and Head of Department of Medicine, Dr. Ziauddin Hospital, Kemari[3]

Corresponding Email: *abid.kazmi@zu.edu.pk*

Abstract

Background: Diabetes Mellitus is among the diseases that have confronted an entire generation; its complication, Diabetic Peripheral Neuropathy (DPN), has impacted many people. DPN has been connected with severe outcomes such as falls and other injuries. Consequently, it is crucial to maintain equilibrium and mobility among the affected people. This review aimed to determine the influence of functional balance exercises on dynamic balance in DPN patients.

Methods: This review focused on randomized controlled trials between 2010 and 2024 wherein functional balance exercises were compared with conventional or a control group regarding outcomes. The BBS, the TUG, and the 6MWT measured these outcomes. A robust search across many databases was conducted. Two reviewers independently extracted the data, rigorously evaluated the quality of all included studies, and performed a random-effects meta-analysis to establish the pooled SMD in balance outcomes.

Conclusion: Ten studies with DPN participants aged 40 to 85 were included. The outcome was a fair BBS score: SMD = 0.458, 95% CI = -0.0179 to 0.933, I^2 = 55.87%. The Timed Up and Go test was significantly improved (SMD = -0.815, 95% CI: -1.458 to -0.172, I^2 = 79.13%), whereas outcomes of the 6-Minute Walk Test were only positive with a small SMD (SMD = 0.341, 95% CI: -0.699 to 1.380, I^2 = 82.65%).

Conclusion: Functional balance exercises are good in improving dynamic balance among patients with DPN, and there is a need for a rehabilitation program tailored to the individual's specific condition in managing complications of diabetes, such as proper exercise regimens.

Keywords

Balance, Diabetes Mellitus, Exercises, Neuropathy.

Cite as: Hameed UA, Kazmi AM, Sohail F. Effectiveness of Functional Balance Exercises on Dynamic Balance in Individuals with Diabetic Peripheral Neuropathy: A Systematic Review and Meta-Analysis. Allied Med Res J. 2024;2(2):335-349. Available from: https://ojs.amrj.net/index.php/1/article/view/235/111.

DOI: https://doi.org/10.59564/amrj/02.02/35 **Received:** 10th April 2024 , **Revised:** 10th June 2024 , **Accepted:** 24th June 2024

Introduction

Diabetes Mellitus (DM) stands as a major global health issue, leading to significant morbidity and mortality rates, especially in developed nations and areas undergoing rapid urbanization[1]. As of 2019, diabetes accounted for about 4.2 million deaths globally, with nearly 463 million adults aged 20 to 79 affected by this condition[2]. Projections suggest a dramatic increase to over 700 million cases by 2030[3]. Particularly in developing countries like Pakistan, which is currently the seventh highest in terms of diabetes prevalence and expected to rise to fourth with a 15% increase by 2030, the surge in diabetes cases is primarily attributed to lifestyle shifts and urbanization[4].

Of the many complications of diabetes, Diabetic Peripheral Neuropathy (DPN) stands out because of its prevalence and the extremely debilitating impact it has on those afflicted[5]. This is because 30% to 50% of individuals with diabetes suffer from DPN, caused by damage to the sensory, motor, and autonomic nerves due to persistently elevated blood glucose levels[6].The main symptoms, such as pain, numbness, and weakness, primarily affect the lower limbs and can lead to severe complications, including ulcers, infections, and amputation[7]. While the exact mechanisms behind DPN are complex and not entirely understood, they are believed to be related to chronic high blood sugar and the resulting metabolic disturbances[8].

Moreover, DPN can impair proprioception and motor function, leading to an increased risk of falls and injuries due to muscle weakness and changes in proprioceptive feedback[9]. The success of exercise interventions in individuals with DPN can be affected by various factors, including the ability to activate nerves, blood flow in small vessels, and how muscles uptake glucose[10-11]. These interventions aim to improve overall health and alleviate symptoms[12]. Consequently, traditional physiotherapy for DPN patients emphasizes strengthening lower body strength and balance through exercises that enhance the range of motion, gait training, and balance exercises[13-14].

Evidence consistently supports the notion that exercise enhances lower extremity strength and balance, thereby mitigating fall risk, particularly among individuals with DPN[15]. Exercise programs, especially those that include functional balance exercises involving resistance, balance, endurance, and coordination training, have proven effective in enhancing muscle strength, coordination, and mobility. These improvements are vital for minimizing the risk of falls among this population[16-18].

However, the literature needs a detailed analysis of the specific impacts of different exercise approaches on balance for those with DPN. This systematic review and meta-analysis seek to fill that gap by examining how functional balance exercises affect dynamic balance in DPN patients. The objective is to compile existing evidence to inform clinical practices and rehabilitation strategies, ultimately improving the quality of life for individuals dealing with this widespread complication of diabetes. This underscores the necessity for more targeted research to refine exercise programs for these at-risk individuals.

Methodology

Study Protocol

The systematic review and meta-analysis methodology adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines[19].

Inclusion Criteria

Only RCTs conducted between 2010 and 2024 and published in English were considered. Comparisons were made between functional balancing exercises with conventional exercises, controls, placebos, or other interventions. Outcomes were evaluated using Berg Balance Scale (BBS), Timed Up and Go Test (TUG), and Six-Minute Walk Test (6MWT), which indicate the likelihood of falls.

Exclusion Criteria

The exclusion criteria included studies that were not randomized, those not published in the preferred language of reporting, and those with insufficient data to be included in the analysis or outcome measures that do not reflect dynamic balance.

Searching Strategy

A broad literature search used Google Scholar, PubMed, PEDro, Cochrane Library, Web of Science, and Scopus. Key terms and phrases, including “functional balancing exercises,” “Berg Balance Scale (BBS),” “Timed Up and Go (TUG),” “6-Minute Walk Test (6MWT),” and their effects on “dynamic balance” outcomes, have been used for the literature search.

Data Extraction

Two independent reviewers (HUA and KAM) collected data using a uniform form to capture critical details such as the author’s name, year of publication, sample size, details of the intervention groups, and the study’s results. Any differences in data interpretation between the reviewers were settled through discussion to ensure the accuracy of the data.

Quality Assessment

The methodological quality of the included studies was assessed using the Cochrane Risk of Bias Tool[20]. This tool evaluated “random sequence generation”, “allocation concealment”, “blinding”, "incomplete outcome data" and "selective reporting". Only studies of acceptable quality were included in the final analysis.

Statistical Analysis

The review utilized a meta-analysis based on mean differences for the statistical analysis. The size of the effects for each study was determined using their magnitudes and classified as small (0.2-0.4), moderate (0.5-0.7), or large (>0.8), following Cohen's criteria[21]. Depending on the heterogeneity observed across the studies, the analysis chose a random-effects model for significant heterogeneity (I2>50%) and a fixed-effects model for lesser variability.

Results

A comprehensive search was conducted across various databases to gather 10,000 articles for initial review. After filtering out 8,000 duplicates, 1,500 articles were screened based on their titles. Further scrutiny led to the exclusion of 600 articles due to issues related to study design, language, and unsuitable comparisons or outcomes, leaving 600 articles for abstract review. Subsequently, 150 full-text articles were assessed for eligibility, including 10 studies (Figure-1).

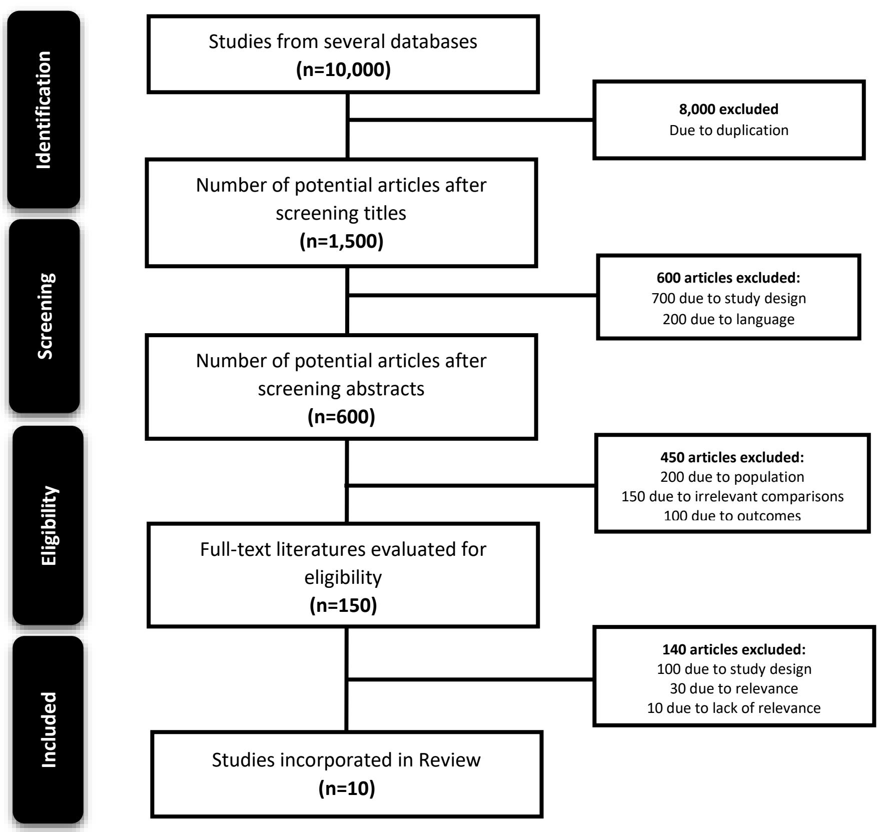

Figure-1 PRISMA Flowchart of Studies Selection

The studies acquired randomized controlled trials on individuals aged 40-85 with DPN. The interventions varied but focused on balance training, proprioceptive exercises, or sensorimotor training. Most studies indicated significant improvements in balance using the BBS and TUG tests. Overall, the results demonstrate that structured exercise programs enhance the functional ability of individuals with diabetes-related complications related to balance and mobility (Table-1).

Table-1 Characteristics of the included studies

Author	Sample Characteristics	Experimental Group	Control Group	Findings
Irshad et al. 2024[22]	RCT, n=40; DPN diagnosed via NDS (≥2) with symptoms like tingling	Balance training 3x/week for 4 weeks	Traditional balance training 3x/week for 4 weeks	There was a significant improvement in balance as indicated by the BBS scores ($p<0.001$)
Abdelbasset et al. 2020[23]	Prospective RCT, n=28; DN, aged 40-60 years	Proprioceptive Exercise Group (PEG) 3x/week for 2 months (toe walking, balance exercises)	Conventional treatment without exercise	The PEG group exhibited significant improvements in BBS ($p = 0.032$) and 6MWT ($p = 0.001$)
Domínguez-Muñoz et al. 2020[24]	Double-blinded RCT, n=90; T2DM patients, aged 40-85 years	Whole-body vibration (WBV) training 3x/week for 8 weeks using Galileo 900	Placebo group (no actual vibration)	Both groups improved in chair stand and TUG tests, but no significant effect of WBV was found
Ahmad et al. 2019[25]	RCT, n=37; DPN, aged 45-75 years	Sensorimotor training 3x/week for 8 weeks (includes warm-up, balance, gait training)	Diabetes education sessions biweekly	Sensorimotor training improved static and dynamic balance (TUG, $p<0.03$)
Rojhani-Shirazi et al. 2016[26]	RCT, n=60; Type II DPN, aged 45-65 years	Frenkel exercise training 5 days/week for 3 weeks	No intervention, clinical balance indices measured	Significant improvement in BBS ($p<0.05$) compared to control

Ghazal et al. 2016[27]	RCT, n=18; diabetic patients assessed via BBS	Task-Oriented Balance Training 3x/week for 8 weeks (cognitive and motor tasks included)	Traditional balance training 3x/week for 8 weeks	A significant improvement in dynamic balance (p<0.05) was observed in the task-oriented group compared to traditional training
Taveggia et al. 2014[28]	Double-blind RCT, n=36; DSP associated with Type 2 diabetes	Multimodal manual treatment, 5 days/week for 4 weeks (balance retraining on dynamic platforms)	Standard care (endurance and manual exercises)	Significant improvement in 6MWT for the experimental group (p = 0.001)
Kutty et al. 2013[29]	RCT, n=32; diabetic males aged 55-75 years	Multisensory exercise training 3x/week for 30 minutes over 6 weeks (various physical activities)	No treatment, received diabetes education weekly	Significant improvement in TUG (t = 14.7092); no significant difference in 6MWT (p = 0.7206)
Lee, Lee and Song, 2013[30]	RCT, n=95; elderly patients with DPN, age ≥ 65 years	Balance exercise program, supervised 60-min sessions 2x/week for 6 weeks (strength, balance, and functional mobility)	No training	The balance exercise program resulted in improved balance, muscle strength, and HbA1c in high-risk elderly patients
Song et al. 2011[31]	RCT, n=38; diabetic patients diagnosed with DPN	Balance exercise 2x/week for 8 weeks (includes warm-up, balance exercises, and cool-down)	Health education once a week for 8 weeks	Significant improvements in dynamic balance (BBS, TUG, p<0.05) were noted following balance exercises

Meta-Analysis on BBS

In five studies, researchers investigated the impact of various interventions on balance using the BBS. The findings revealed a moderate effect size (SMD=0.458; 95%CI = -0.0179 to 0.933). There was notable variability among the studies, as evidenced by an I^2 value of 55.87% and a Q statistic of 9.0636, with a p-value of 0.0595 (Table-2, Figure-2).

Table-2 SMD from meta-analysis of studies utilizing BBS outcome measure										
Study	N1	N2	Total	SMD	SE	95% CI	T	P	Weight (%)	
									Fixed	Random
Irshad et al. 2024	20	20	40	0.218	0.311	-0.412 to 0.847			25.58	22.61
Abdelbasset et al. 2020	14	14	28	0.841	0.384	0.0523 to 1.630			16.79	18.88
Rojhani-Shirazi et al. 2016	20	20	40	0.730	0.321	0.0811 to 1.379			24.07	22.09
Ghazal et al. 2016	8	10	18	1.044	0.484	0.0180 to 2.070			10.55	14.71
Lee, Lee and Song, 2013	18	18	36	-0.301	0.328	-0.968 to 0.365			23.00	21.70
Total (fixed effects)	80	82	162	0.414	0.157	0.103 to 0.724	2.630	0.009	100.00	100.00
Total (random effects)	80	82	162	0.458	0.241	-0.0179 to 0.933	1.901	0.059	100.00	100.00
Test for heterogeneity										
Q	9.0636									
DF	4									
Significance level	P = 0.0595									
I^2 (inconsistency)	55.87%									
95% CI for I^2	0.00 to 83.68									

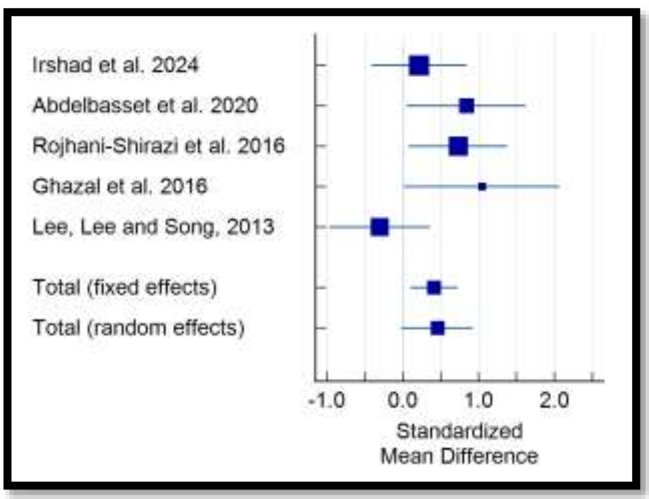

Figure-2 Forest plot of the effect of functional balance exercises on BBS

Meta-Analysis on TUG

A meta-analysis of TUG test results across five studies demonstrated a clinically significant deleterious effect size in favor of the interventions, with pooled SMD = -0.815 (95% CI: -1.458 to -0.172) using the random effect model. The study also showed significant heterogeneity, where I^2 = 79.13%, and the Q-statistic for that study was 19.1677 (p = 0.0007), confirmed to establish variability among the studies (Table-3, Figure-3).

Table-3 SMD from meta-analysis of studies utilizing TUG outcome measure										
Study	N1	N2	Total	SMD	SE	95% CI	T	P	Weight (%)	
									Fixed	Random
Domínguez-Muñoz et al. 2020	45	45	90	-0.0441	0.209	-0.460 to 0.371			44.31	23.57
Ahmad et al. 2019	12	9	21	-1.474	0.481	-2.480 to -0.468			8.39	16.67
Lee, Lee and Song, 2013	18	18	36	-0.354	0.329	-1.022 to 0.313			17.93	20.64
Song et al. 2011	19	19	38	-0.774	0.330	-1.443 to -0.105			17.80	20.61
Kutty et al. 2013	16	16	32	-1.764	0.409	-2.599 to -0.928			11.57	18.51
Total (fixed effects)	110	107	217	-0.548	0.139	-0.823 to -0.274	-3.942	<0.001	100.00	100.00
Total (random effects)	110	107	217	-0.815	0.326	-1.458 to -0.172	-2.497	0.013	100.00	100.00
Test for heterogeneity										
Q	19.1677									
DF	4									
Significance level	P = 0.0007									
I^2 (inconsistency)	79.13%									
95% CI for I^2	50.38 to 91.22									

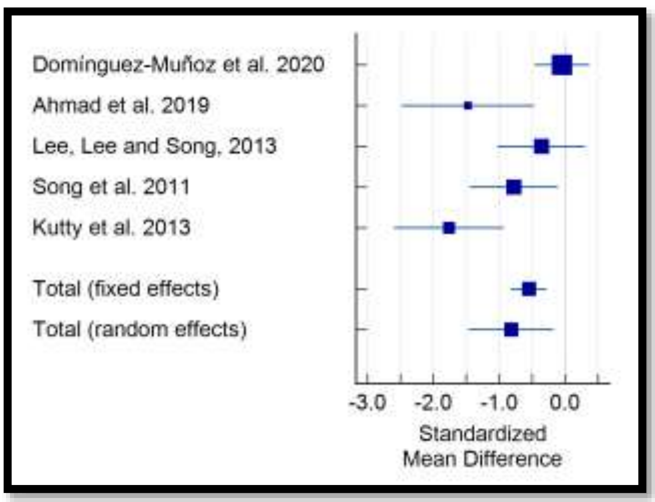

Figure-3 Forest plot of the effect of functional balance exercises on TUG

Meta-Analysis on 6MWT

From a random effects model, the 6MWT meta-analysis across three studies indicated a small positive effect size with a pooled SMD of 0.341 (95% CI: -0.699 to 1.380). However, significant heterogeneity existed among the studies having an I^2 value of 82.65%, and the Q statistic of 11.5299 (p = 0.0031) further confirmed this substantial variability (Table-4, Figure-4).

Table-4 SMD from meta-analysis of studies utilizing TUG outcome measure										
Study	N1	N2	Total	SMD	SE	95% CI	t	P	Weight (%)	
									Fixed	Random
Irshad et al. 2024	14	14	28	1.352	0.409	0.511 to 2.192			28.08	32.37
Taveggia et al. 2014	14	13	27	0.192	0.374	-0.579 to 0.964			33.50	33.44
Kutty et al. 2013	16	16	32	-0.471	0.350	-1.185 to 0.243			38.42	34.19
Total (fixed effects)	44	43	87	0.263	0.217	-0.168 to 0.694	1.213	0.228	100.00	100.00
Total (random effects)	44	43	87	0.341	0.523	-0.699 to 1.380	0.652	0.516	100.00	100.00
Test for heterogeneity										
Q	11.5299									
DF	2									
Significance level	P = 0.0031									
I^2 (inconsistency)	82.65%									
95% CI for I^2	46.92 to 94.33									

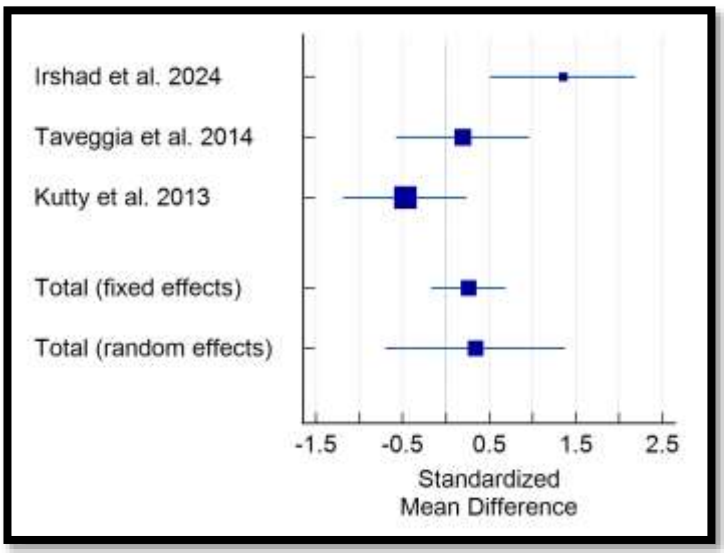

Figure-4 Forest plot of the effect of functional balance exercises on 6MWT

Qualitative Analysis of Studies

The studies had an overall risk of bias that was assessed through the authors' judgment, as shown in Table-5, using the Cochrane Risk of Bias Tool:

- ***Random Sequence Generation***
  All studies had adequate processes for randomization. There is no risk of selection bias because of this.

- ***Allocation Concealment***
  All studies had well-concealed allocation, which reduced the risk of selection bias.

- ***Blinding of Participants and Personnel***
  Six studies [22, 23, 26, 27, 29, 31] did not blind the participants and personnel, thus a higher risk of bias. One study had unknown risk[30], and the rest had a low risk of bias.

- ***Blinding of Outcome Assessors***
  Three studies[22, 27, 29] did not have blinding outcome measures: high risk of bias. Studies[25,31] had an unknown bias, and the rest had low risk due to blinding of outcome assessors.

- ***Incomplete Outcome Data***
  All studies effectively managed incomplete outcome data, demonstrating a low risk of attrition bias.

- ***Selective Reporting***
  Selective reporting was not identified as a significant issue, ensuring the transparency of results and a low risk of reporting bias.

Table-5 Quality Assessment of Included Studies

Study	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessors	Incomplete Outcome Data	Selective Reporting
Irshad et al. 2024[22]	✓	✓	×	×	✓	✓
Abdelbasset et al. 2020[23]	✓	✓	×	✓	✓	✓
Domínguez-Muñoz et al. 2020[24]	✓	✓	✓	✓	✓	✓
Ahmad et al. 2019[25]	✓	✓	✓	?	✓	✓
Rojhani-Shirazi et al. 2016[26]	✓	✓	×	✓	✓	✓
Ghazal, Malik and Amjad, 2016[27]	✓	✓	×	×	✓	✓
Taveggia et al. 2014[28]	✓	✓	✓	✓	✓	✓
Kutty and Majid, 2013[29]	✓	✓	×	×	✓	✓

Lee, Lee and Song, 2013[30]	✓	✓	?	✓	✓	✓
Song et al. 2011[31]	✓	✓	×	?	✓	✓

Discussion

The scholarly consensus underscores the beneficial impact of balance training on individuals with DPN. Various research has documented notable enhancements in balance following structured exercise regimens. For instance, research by Irshad and colleagues[22] highlighted marked progress in a group undergoing innovative balance training compared to those engaging in traditional balance exercises. Rojhani-Shirazi et al.[26] and team found that Frenkel exercises, which use visual cues and controlled movements, effectively bolstered balance, using the BBS for evaluation. Ghazal et al.[27] reported that task-specific training improved balance and diminished the risk of falls among DPN sufferers. Additionally, a study by Lee and associates[30] showed that incorporating WBV into a balanced exercise regimen significantly improved BBS scores and performance on functional tests like the TUG test, a measure of functional mobility and various aspects of balance and walking. These findings advocate for including targeted training protocols to enhance balance and minimize the risk of falls in this group.

Ahmad et al.[25] conducted research that emphasized the benefits of sensorimotor training in significantly enhancing dynamic balance and proprioception among middle-aged and older individuals suffering from DPN. The balance interventions noted a dynamic balance advance of this nature; the effectiveness of specific interventions in advancing instances is underscored. Even though minimal advance exists within the static balance spectrum of the aged population, their research was relevant in pointing to age-related variations in these interventions, which must be specifically tailored for this population group. This provides substantial evidence for the claim that balance training can reduce the rate of falls among elderly populations. Studies on WBV and sensorimotor training are a comprehensive and enlightening effort aimed at handling the complexities of DPN. Though WBV strongly impacted body fat, effects on important health markers like HbA1c and total mobility were insignificant, leading the authors to conclude that passive interventions, such as those provided here, cannot fully address the multi-level challenge of DPN[28].

Sensorimotor training has emerged as a promising means to enhance balance rapidly. Such a program should be lively and well-individualized to attend to each need of the DPN patient. The extent to which such findings are validated lies in using established scales, such as the BBS, TUG, and 6MWT. Each of these measures assesses different dimensions of balance and mobility that would make for a more holistic evaluation of the effect of such intervention. Although, there are also some limitations. Most of the studies have very few cases in their sample size, and a follow-up study for more extended periods is needed to justify the generalizability of these findings.

Future studies should be replicated with higher sample sizes and longer follow-ups to establish long-term changes due to improved balance. Further, future studies should investigate pain levels and how multitasking activities can influence the effectiveness of the training programs. Additionally, with high technologies incorporating virtual reality and sensor-based feedback mechanisms, engagement may be increased and will, eventually, heighten the effectiveness of balance training programs.

Conclusion

This systematic review with meta-analysis provides strong evidence that performing functional balance exercises will significantly improve the dynamic balance of patients with DPN. Moderate results on the BBS are verified, while significant improvements on the TUG validate the use of these exercises to achieve stability and reduce risks of falls in this group. Since falls are a chief cause of complications in patients suffering from DPN, exercises that target balance must also be considered as an essential part of rehabilitation protocols for the future to aim towards designing the best exercise protocol, with long-term benefits and underlying mechanisms that lead to better quality of life and independence for diabetic patients with decreased incidence of such complications.

Acknowledgments
None.

Conflict of Interest
None.

Grant Support and Funding Disclosure
None.

References

1. Arokiasamy P, Salvi S, Selvamani Y. Global burden of diabetes mellitus. InHandbook of global health 2021 May 4 (pp. 1-44). Cham: Springer International Publishing.
2. Harding JL, Weber MB, Shaw JE. The Global Burden of Diabetes. Textbook of Diabetes. 2024 Feb 7:28-40.
3. Rowley WR, Bezold C, Arikan Y, Byrne E, Krohe S. Diabetes 2030: insights from yesterday, today, and future trends. Population health management. 2017 Feb 1;20(1):6-12.
4. Saeedi P, Petersohn I, Salpea P, Malanda B, Karuranga S, Unwin N, Colagiuri S, Guariguata L, Motala AA, Ogurtsova K, Shaw JE. Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas. Diabetes research and clinical practice. 2019 Nov 1;157:107843.

5. Iqbal Z, Azmi S, Yadav R, Ferdousi M, Kumar M, Cuthbertson DJ, Lim J, Malik RA, Alam U. Diabetic peripheral neuropathy: epidemiology, diagnosis, and pharmacotherapy. Clinical therapeutics. 2018 Jun 1;40(6):828-49.
6. Pop-Busui R, Ang L, Boulton AJ, Feldman EL, Marcus RL, Mizokami-Stout K, Singleton JR, Ziegler D. Diagnosis and treatment of painful diabetic peripheral neuropathy.
7. Sloan G, Pan Q, Gao L, Guo L, Tesfaye S. Clinical features of diabetes neuropathies. InDiabetic Neuropathy: Advances in Pathophysiology and Clinical Management 2023 Mar 21 (pp. 37-49). Cham: Springer International Publishing.
8. Galiero R, Caturano A, Vetrano E, Beccia D, Brin C, Alfano M, Di Salvo J, Epifani R, Piacevole A, Tagliaferri G, Rocco M. Peripheral neuropathy in diabetes mellitus: pathogenetic mechanisms and diagnostic options. International Journal of Molecular Sciences. 2023 Feb 10;24(4):3554.
9. BHATT U, MEHTA M, KUMAR GP. Postural Control in Diabetic Peripheral Neuropathy: A Narrative Review. Journal of Clinical & Diagnostic Research. 2022 Apr 1;16(4).
10. Holmes CJ, Hastings MK. The application of exercise training for diabetic peripheral neuropathy. Journal of clinical Medicine. 2021 Oct 28;10(21):5042.
11. Enders J, Wright DE. Lifestyle and Dietary Modifications: Relevance in the Management of Diabetic Neuropathy. InDiabetic Neuropathy: Advances in Pathophysiology and Clinical Management 2023 Mar 21 (pp. 397-414). Cham: Springer International Publishing.
12. Streckmann F, Balke M, Cavaletti G, Toscanelli A, Bloch W, Décard BF, Lehmann HC, Faude O. Exercise and neuropathy: systematic review with meta-analysis. Sports Medicine. 2022 May;52(5):1043-65.
13. Atre JJ, Ganvir SS. Effect of functional strength training versus proprioceptive neuromuscular facilitation on balance and gait in patients with diabetic neuropathy. Indian Journal of Physical Therapy and Research. 2020 Jan 1;2(1):47-54.
14. Ahmad I, Verma S, Noohu MM, Shareef MY, Hussain ME. Sensorimotor and gait training improves proprioception, nerve function, and muscular activation in patients with diabetic peripheral neuropathy: a randomized control trial. Journal of musculoskeletal & neuronal interactions. 2020;20(2):234.
15. Alissa N, Shipper AG, Zilliox L, Westlake KP. A Systematic Review of the Effect of Physical Rehabilitation on Balance in People with Diabetic Peripheral Neuropathy Who are at Risk of Falling. Clinical Interventions in Aging. 2024 Dec 31:1325-39.
16. McLaughlin EC, El-Kotob R, Chaput JP, Janssen I, Kho ME, Poitras VJ, Ross R, Ross-White A, Saunders TJ, Sherrington C, Giangregorio LM. Balance and functional training and health in adults: an overview of systematic reviews. Applied Physiology, Nutrition, and Metabolism. 2020;45(10):S180-96.
17. Lichtenstein E, Morat M, Roth R, Donath L, Faude O. Agility-based exercise training compared to traditional strength and balance training in older adults: a pilot randomized trial. PeerJ. 2020 Apr 14;8:e8781.

18. Alonso-Enríquez L, Gómez-Cuaresma L, Billot M, Garcia-Bernal MI, Benitez-Lugo ML, Casuso-Holgado MJ, Luque-Moreno C. Effectiveness of Virtual Reality and Feedback to Improve Gait and Balance in Patients with Diabetic Peripheral Neuropathies: Systematic Review and Meta-Analysis. InHealthcare 2023 Nov 24 (Vol. 11, No. 23, p. 3037). MDPI.
19. Parums DV. Review articles, systematic reviews, meta-analysis, and the updated preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 guidelines. Medical science monitor: international medical journal of experimental and clinical research. 2021;27:e934475-1.
20. Faggion CM. Methodological quality, risk of bias, and reporting quality: A confusion persists. Journal of Evidence-Based Medicine. 2023 Sep 1;16(3).
21. Lovakov A, Agadullina ER. Empirically derived guidelines for effect size interpretation in social psychology. European Journal of Social Psychology. 2021 Apr;51(3):485-504.
22. Maqbool S, Irshad M, Nisa MU, Munir R, Farooqi M, Nasir M, Ahmad M, Gohar S, Asif J, Akram S, Arshad H. A Randomized Control Study of Effectiveness of Aerobic Exercise Training and Balance Training on Balance in Patients with Diabetic Peripheral Neuropathy. Journal of Health and Rehabilitation Research. 2024 Aug 9;4(3):1-7.
23. Abdelbasset WK, Alrawaili SM, Nambi G, Yassen E, Moawd SA, Ahmed AS. Therapeutic effects of proprioceptive exercise on functional capacity, anxiety, and depression in patients with diabetic neuropathy: a 2-month prospective study. Clinical rheumatology. 2020 Oct;39:3091-7.
24. Domínguez-Muñoz, F.J., Villafaina, S., García-Gordillo, M.A., Hernández-Mocholi, M.Á., Collado-Mateo, D., Adsuar, J.C. and Gusi, N., 2020. Effects of 8-week whole-body vibration training on the HbA1c, quality of life, physical fitness, body composition and foot health status in people with T2DM: A double-blinded randomized controlled trial. *International Journal of Environmental Research and Public Health*, *17*(4), p.1317.
25. Ahmad I, Verma S, Noohu MM, Hussain ME. Effect of sensorimotor training on spatiotemporal parameters of gait among middle and older age adults with diabetic peripheral neuropathy. Somatosensory & Motor Research. 2021 Jul 3;38(3):230-40.
26. Rojhani-Shirazi Z, Barzintaj F, Salimifard MR. Comparison the effects of two types of therapeutic exercises Frenkele vs. Swiss ball on the clinical balance measures in patients with type II diabetic neuropathy. Diabetes Metab Syndr. 2017 Nov;11 Suppl 1:S29-S32. doi: 10.1016/j.dsx.2016.08.020. Epub 2016 Sep 15. PMID: 27720359.
27. Ghazal J, Malik AN, Amjad I. Task oriented training improves the balance outcome & reducing fall risk in diabetic population. Pak J Med Sci. 2016 Jul-Aug;32(4):983-7. doi: 10.12669/pjms.324.10092. PMID: 27648053; PMCID: PMC5017116.
28. Taveggia G, Villafañe JH, Vavassori F, Lecchi C, Borboni A, Negrini S. Multimodal treatment of distal sensorimotor polyneuropathy in diabetic patients: a randomized clinical trial. J Manipulative Physiol Ther. 2014 May;37(4):242-52.

29. Kutty NAM, Majida NAL. Effects of Multisensory Training on Balance and Gait in Persons with Type 2 Diabetes: A Randomised Controlled Trial. DCIDJ [Internet]. 2013 Jul. 28;24(2):79-91.
30. Lee K, Lee S, Song C. Whole-body vibration training improves balance, muscle strength and glycosylated hemoglobin in elderly patients with diabetic neuropathy. Tohoku J Exp Med. 2013 Dec;231(4):305-14.
31. Song CH, Petrofsky JS, Lee SW, Lee KJ, Yim JE. Effects of an exercise program on balance and trunk proprioception in older adults with diabetic neuropathies. Diabetes Technol Ther. 2011 Aug;13(8):803-11.

AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

Conception or Design: Hameed UA, Kazmi AM

Acquisition, Analysis or Interpretation of Data: Hameed UA, Kazmi AM, Sohail F

Manuscript Writing & Approval: Hameed UA, Kazmi AM, Sohail F

All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Copyright © 2024. Hameed, Kazmi and Sohail. This is an Open Access article distributed under the terms of the Creative Commons Attribution-Non-commercial 4.0 International License, which permits unrestricted use, distribution & reproduction in any medium provided that original work is cited properly.