



ROLE OF EXERCISE THERAPY IN IMPROVEMENT OF BALANCE AND GAIT IN PATIENTS WITH DIABETIC NEUROPATHY: A REVIEW

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ABSTRACT As we know diabetic neuropathy is most common complication of both type 1 and 2 diabetes it affects over 90% of the all patients that are suffering with diabetes mellitus and diabetic neuropathy has a negative impact on postural balance and gait kinematics. So this study is reviewed in a narrative way to find the current evidences based studies in improving the balance and gait in peoples with diabetic neuropathy. A electronic database, search by title and abstract was conducted in between year 2012 to 2022 by using Google Scholar, PubMed, Physiotherapy evidence database (PEDro) and Cochrane databases. The studies were double checked and only full text articles were used for the review. Total 15 studies were selected to demonstrate the role of exercise therapy in improving balance and gait in DPN patients. According to database search on December 2022 from Jan 2012 to November 2022, about 16 free full text articles founded that shows the effectiveness of exercise therapy on balance and gait by different approaches used for balance and gait training in DNP. Current data suggest that exercise therapy is safe and feasible and is found to improve balance and gait of patients with DPN. Specific exercise programs, including range of motion, muscle-strengthening circuit training, stretching, gait and balance exercises, can improve gait and balance in diabetics with peripheral neuropathy.

KEYWORDS : Exercise therapy, gait, balance, neuropathy, diabetes mellitus**INTRODUCTION**

Diabetes Mellitus is a group of metabolic disorders which is characterized by a chronic hyperglycemic condition resulting from defects in insulin secretion, insulin action or both.¹ It is a very common devastating medical condition that has increased in prevalence over the past few decades to constitute a major public health challenge of the twenty-first century.² In adults with diabetes mellitus more than 95% have type 2 diabetes mellitus.³ Chronic hyperglycemia is the main factor that play a major role in pathogenic mechanisms of micro vascular (retinopathy, neuropathy) and macro vascular (peripheral vascular disease, cardiovascular disease) complications in diabetes.⁶

Diabetic neuropathy is most common complication of both type 1 and 2 diabetes it affects over 90% of the all patients that are suffering with diabetes mellitus.⁴ People do not consider it a serious problem because, unlike many other diseases, the consequences of hyperglycemia do not appear immediately. People are not aware that damage can start several years before symptoms become noticeable.⁵ It manifests in the somatic and autonomic parts of the peripheral nervous system. Diabetic sensorimotor polyneuropathy is the commonest form it affects approximately 30% of individuals with diabetes and its yearly incidence amounts to approximately 2%. DSPN is defined as an abnormal pressure, temperature and/or vibration sensation in the presence of pain and/or burning or paresthesia, numbness or absence of symptoms in the legs.⁷

The implication of biomechanical abnormalities caused by DPN is leading factors to the development diabetic foot problems and traumatic falls and also diabetic neuropathy has a negative impact on postural balance and gait kinematics for an increased fall risk.⁸ Previously it was reported that, the effect on gait and balance status among older people might be related to several parameters, including pain, loss of sensation, loss of reflexes, and diminished strength.⁹

Today, many rehabilitation methods are used in the treatment of patients with diabetic neuropathy. These include pharmacological drugs, manual therapy, electrotherapy methods, acupuncture and exercise therapy.¹¹ Physiotherapy for patients with peripheral neuropathy has gained increasing interest over the past decade, but evidence for its efficacy and safety is emerging. The purpose of this narrative review is to describe the current evidence for the effectiveness and safety of physical therapy in improving balance and gait in patients with peripheral neuropathy and to suggest directions for future research.¹⁰ However; in exercise therapy, much attention has been given to improving the walking functions of people with DPN.¹¹ A therapeutic exercise program that includes various movement activities, muscle strengthening, circuit exercises, walking exercises and balance exercises.¹²

Balance disturbance in Diabetic patients

Balance is the maintenance of a person's center of mass within their area of stability, meaning the area within the center of the mass can be moved safely without changing the base of support.¹³ The ability to maintain balance is a complex skill that requires the integration of several sensorimotor and cognitive processes. The somatosensory system provides information about the position and movement of body parts in relation to each other and the support surface using proprioceptive and skin inputs, visual information about the environment and the direction of the body, the vestibular system provides information about the position of body parts, orientation of head and room.¹⁴

Diabetics have more balance problems than the rest of the population and are at a higher risk of falling. Some studies suggest that this may be due to a combination of proprioception, vision and possible damage to the vestibular system from prolonged hyperglycemia.¹⁵ Some authors also hypothesized that presence of diabetic neuropathy may impair the balance of the affected patients mediated by the problems associated with all of its three major components that are lack of motion associated with sensory system, impairments in movement coordination and the presence of postural hypotension that may be a autonomic dysfunction.¹⁶

Gait alteration in Diabetic patients

Normal walking is the end product of a healthy neuromuscular-skeletal system, which requires both sensory input to change learned motor patterns and muscle strength to perform the desired action. Walking is a key part of physical activity. A healthy central and peripheral nervous system to initiate and control movement, adequate muscle strength, and fully mobile bones and joints are essential for normal movement, the most natural human activity of daily life. In addition, most falls occur in situations where a person is walking.²⁰ DPN is a significant consequence of diabetes and can have a detrimental effect on the gait of people with this complication.¹⁷ Patients with diabetes walk more slowly and with a shorter stride, longer stance phase, wider base of support and greater stride time. changeability on irregular surfaces and improper distribution of pressure in the foot compared to nondiabetic individuals.¹⁸ These factors are thought to include sensory impairment (neuropathic ulcers, impaired tremor), reduced lower limb strength (energy production), and central nervous system dysfunction. impaired gait.¹⁹

METHOD

An electronic database, title and abstract search was conducted between 2012 and 2022 using Google Scholar, PubMed, Physiotherapy Evidence Database (PEDro) and Cochrane databases. The search terms used were "diabetes mellitus", "type 2 diabetes", "diabetic neuropathy", "diabetic peripheral neuropathy", "balance", "gait", "fall risk", "proprioception", "demand control", "postural

stability", "balance training" and "balance training", walking training. Articles that assessed variables on balance and gait characteristics and the effects of balance and gait training provided independently or in combination with other training to DPN patients were included. Exercises other than balance and gait training were excluded. Studies were double-checked and only full-text articles were used in the review. A total of 15 studies were selected that demonstrated the role of exercise therapy in improving balance and gait in patients with DPN. These studies were explored narratively.

Treatment methods for improvement of balance and gait

There is evidence that an exercise program improves clinical balance scores in patients with peripheral neuropathy.²¹ Exercise, including strength and balance exercises, as well as aerobic exercise, can increase blood, oxygen, and glucose supply to mitochondria, allowing mitochondria to produce more energy, effectively. Increases in mitochondrial energy production and peripheral nerve blood flow can reduce neuropathic symptoms, increase strength and balance, and improve quality of life.²² Some studies suggest that balance training appears to be the most effective exercise intervention.²³ Some authors also conclude that, according to these studies, a specific exercise program that includes movement, muscle strengthening, walking and balance exercises, improves walking in diabetics.²⁴

The following are some evidence-based studies that suggest different strategies to improve gait and balance in patients with diabetic neuropathy:

Mohammad Akbari et al (2012) investigated the effect of balance exercises on the swing indices of diabetic patients with neuropathy. This study included 10 diabetic patients with peripheral neuropathy using simple non-probability sampling and 10 nondisabled subjects of the same age. Before the intervention, the balance ability of the participants in both groups was examined using the Biodex balance system. The experimental group was retested after the procedure. The intervention consisted of progressive Biodex stability and rocker and wobble board training over 10 sessions. All experiments were performed with eyes open and closed, standing on both sides. After the intervention, the experimental group was re-examined in the same way. Student's t-test and paired t-test were used to analyze the data. The total stability index and AP stability index significantly decreased after treatment of the experimental group under different conditions. Balance indices in the experimental group were significantly higher than those in the control group before treatment. After treatment, there was no significant difference in rates between the two groups. The results of this study showed that balance training can improve the stability indices in people with DPN.²⁵

Basant hamdy el-refay et al (2013) evaluated the effect of a rehabilitation program on gait of DPN patients. In this study, they had thirty patients with DPN who were randomly assigned to an intervention group (n = 15) and a control group (n = 15). The intervention consisted of an exercise program that included ROM, muscle strengthening, balance and walking exercises. Controls received standard recommended treatment only. Temporal spatiotemporal parameters and ankle ROM during the stance phase of walking were measured at baseline and after the procedure. The intervention program significantly increased speed of walking, number of steps and ankle range of motion with a significant reduction in walking time (p<0.05). The conclusion of this study was that a selected exercise program can improve walking speed, cadence, stride time and ankle range of motion in diabetic patients.²⁴

Kyoungjin Lee et al (2013) conducted this study to find out the effects of a whole-body vibration and balance training program on balance, strength of muscles and glycosylated hemoglobin (HbA1c) in elder people with DPN. 55 elder people with diabetic neuropathy were randomly allocated to a whole-body vibration with a balance exercise group, a balance exercise group, and a control group. The WBV and BE groups performed a balanced exercise program for 60 minutes a day 2 times a week for 6 weeks. In addition, the WBV group performed WBV exercises (up to 3 × 3 min, 3 times a week for 6 weeks). The control group did not included in any training. The most important outcome measures were assessed after 6 weeks of training. They assessed posture and one-legged position for static balance; BBS, TUG and functional range test for dynamic balance; sit-to-stand test 5 times to measure muscle strength; and HbA1c to predict diabetes progression. A significant improvement in static and dynamic balance, strength of muscles and HbA1c was observed in the WBV group

compared to the BE and control groups (P < 0.05). Thus, short-term WBV treatment combined with a balanced exercise program was beneficial in improving balance, muscle strength, and HbA1c in elderly patients with diabetic neuropathy who were at high risk of falling.²⁶

Bina Eftekhari-Sadat et al. (2015) investigated this randomized clinical trial. Here, 34 elder people with DN were divided into intervention group (n = 17) and control group (n = 17). The intervention group was given a balance training program with the Biodex Balance System for 10 training sessions. All subjects in both groups were evaluated at the beginning and end of the study using the timed TUG test, BBS, and fall risk and postural stability tests. The result shows Timed up and go (p = 0.01), fall risk index (p = 0.002), anterior/posterior index (p = 0.01), medial/lateral index (p = 0.04), general stability index (p = 0.01) and the balance from BBS (p = 0.04) significantly improved after training in the intervention group but had no significant changes in the control group. Changes in TUG (p<0.001) and fall risk index (p<0.001) in the intervention group were significantly greater than in the control group. Overall, they concluded from this study that balance training with BBS significantly improved TUG, Berg Balance Scale and BBS indices, especially the falling risk in the experimental group.²⁷

Hoda Salsabili et al (2016) conducted this study to investigate the effects of Task-Oriented Motor Training on gait characteristics of people with type 2 DN. This study included 14 people with DN. All patients participated in four assessments. Exercises took place twice a week for 12 weeks. Vertical and horizontal ground reaction forces, rise and fall time, and FES-I were evaluated. Foot training began with step patterns that gradually evolved into complex walking patterns. The training then continued with a combination of walking patterns with upper extremity exercises and ended with treadmill step training. Its results showed that patients with DN significantly increased the second peak vertical force and horizontal thrust and decreased the minimum vertical force. TGUG significantly decreased, while FES-I reflected a significant increase after walking training. They concluded that walking training together with movement learning principles allowed patients to progress effectively through the sessions.²⁸

K. Kamatchi et al. (2018) conducted this study to see the effectiveness of proprioception training and backward walking training among DN patients. In this study 30 patients both male and female were selected from clinically diagnosed DN. Group A participants received proprioception training and Group B participants received reverse walking exercise for the entire lower limb. Proprioceptive training includes one leg balance, front leg switch with knee extension, back leg swing with knee flexion, toe walk, heel walk, cross leg swing to the right and left side, partial squat, one leg swing, blind advanced one leg balance, and side birth for 45 min and 1 min of rest for every 5 min of exercise for about 12 weeks and reverse walking training in a corridor of 50 m, two paths on both sides of the path with a total length of 10 m and a width of 5 m. m are marked with reflective tape, after which the patient walked backwards with a normal step barefoot for 12 weeks of reverse walking training, 3 times a week, in 1 min increments starting from 20 minutes, the longest training time was 40 minutes and the weekly training time was no more than 100 min. The result was that when comparing the averages of group A and group B in BBS scores, the post-test averages increased significantly, but group A shows (52.00) with a higher average, more effective than group B (43.20). at P < 0.001. Similarly, a comparison of group A and group B means in Time Up and Go Test Score shows a significant reduction in post-test means, but group A shows (4.53) with a lower mean is more effective than group B (7.53) at P < 0.001. Above comparing pre- and post-test in group A and group B using BBS and time up and go test shows a highly significant difference in means at P ≤ 0.001. Therefore, they concluded that proprioceptive training was better than reverse walking training in improving lower limb proprioception.²⁹

Chiranjeevi Jannu et al. (2017) conducted this study to investigate the effectiveness of stability training exercises compared with wobble board exercises for balance retraining in patients with DN. Subjects who met the inclusion criteria will be randomly divided into two groups, namely Group A and Group B, each containing 25 patients. In group A subjects were given treatment with wobble board exercises for 15 minutes and in group B with stability exercises. In addition, both groups were treated with conventional treatment for 30 minutes. Observed differences were tested using Wilcoxon signed rank test, Mann Whitney U test, dependent and independent t-test at a significance level of 5%. A comparison of the post-test values of BBS

and TUG in group A and group B showed a significant difference, that is, it showed that the improvement of group B was significantly more effective than that of group A.¹

Ilaria Zivi et al (2017) conducted this study to compare the effects of aquatic physical therapy on walking and balance on land versus exercise in an inpatient rehabilitation context adapted for peripheral neuropathies. This was a parallel group, single-center, single-blind, randomized controlled trial. Patients were randomly allocated to an experimental or control group. All patients underwent a 4-week inpatient rehabilitation program consisting of the following daily sessions: (1) traditional personal training with a therapist (1 hour/day, five days/week), (2) device training under the guidance of a therapist (treadmill, cycle ergometer, stabilometric platform; 1 hour/day, six days/week); (3) Occupational therapy (1 hour/day, five days/week). Three days a week (Monday, Wednesday, Friday), the first training session was performed with specific personal training in one of two different environments according to the group: a heated (32 °C) test pool ("in water") group and "on-land" for the controls. Comparing the groups, we found that "in water" patients had a significantly better dynamic gait index score (6.00 (4.00, 7.25) vs. 4.00 (1.25, 6.00), $P=0.0433$). In contrast, the "ground" group showed a greater improvement in functional ambulatory evaluations (1.0 (0.75, 1.0) vs. 1.0 (1.0, 2.0), $P = 0.0386$). Thus, they concluded that aquatic physiotherapy had a comparable effect to land-based rehabilitation on gait and balance disorders in neuropathic patients.³⁰

Vida Farhan et al (2018) investigated the effect of combined exercise (ROM improvement, muscle strengthening, balance and gait training) on balance and fall risk in older women with DPN. These include a total of 23 DPN patients who were randomly assigned to experimental ($n = 11$) and control ($n = 10$) groups. Before and after training, balance and fall risk were measured with the BBS and fear of falling tests. The experimental group participated in combined training for 8 weeks, 3 sessions per week and 1 hour per session; the control group did not provided any exercise program. Data were analyzed using independent and paired sample t-tests at a significance level of $p < 0.05$. The results showed that there were significant differences in the balance and fall risk of the experimental group after the combined training, while no significant differences in these scores in the control group were noted. They concluded that combined exercise improves balance and reduces the possibility of falling in elderly women with diabetic DPN.³¹

Sowjanya Maruboyina et al (2018) investigated this study to compared exercises on two unstable surfaces to improve balance and gait in patients with DPN. 30 participants with DN were randomly divided into two groups; Group A ($n=15$) performed exercises on a wobble board and group B ($n=15$) performed exercises on a stability disc for 30 minutes for 8 weeks. Balance before and after intervention was assessed by BBS and gait was assessed by TUG. BBS results were analyzed using non-parametric tests and TUG scores were analyzed using t-tests. Differences in observed values were Z-tested at a 95% significance level ($p<0.05$). Both groups showed good results in recovery after the study. Subjects trained on the stability disc showed a significant improvement compared to subjects trained on the wobble board ($p<0.05$). Therefore, they conclude that the stability disc is more effective than the wobble board in improving balance in patients with diabetic neuropathy.³²

Erica Shih-Wei Hung et al (2019) conducted this study to know the effects of interactive video game based exercise on balance in patients with DPN. Twenty four patients were randomly divided into two groups. Group A received IVGB training the first 6 weeks without training during the following 6 weeks. Group B did not exercise for the first 6 weeks and then underwent IVGB training for the next 6 weeks. The IVGB balance training program consisted of 30 minutes of exercises 3 times a week for 6 weeks. All participants were administered the Modified Fall Efficacy Scale, TUG, BBS and Unipedal Stance Test at weeks 0, 6 and 12 of the experiment. BBS, right leg UST, and TUG test scores significantly improved after the IVGB procedure, while MFES and UST test of the left leg improved after the IVGB procedure. Thus, this study showed that 6 weeks of balance training with the IVGB system had a positive effect on functional balance in patients with diabetic peripheral neuropathy.³³

Marwa Shafiek Saleh et al (2019) investigated the effects of ankle proprioceptive training on gait and risk of fall in people with diabetic neuropathy. 30 diabetic neuropathy patients of both sexes were

randomly divided to a study or control group. The study group ($n=15$) received ankle proprioceptive training along with conventional physical therapy exercises, while the control group ($n=15$) received only conventional physical therapy exercises, 3 times a week for eight weeks. Spatiotemporal gait parameters (gait speed (cm/s), dominant limb step length (cm), step time in seconds, cadence (step/min), double support time also in seconds and fall risk were assessed for all patients in both groups before and after the treatment program. The results of this study showed that there was no significant difference between the two groups in the pretreatment means of all measured variables. A significant improvement was observed between the results measured before and after treatment in the two groups. In addition, the study group recorded a significantly better improvement in all measured variables compared to the control group. They concluded that ankle proprioceptive training can be an excellent addition to traditional physical therapy exercises used to improve gait and reduce the risk of falls in peoples with diabetic neuropathy.³⁴

Ajitha M et al (2020) conducted this study to investigate the effectiveness of stability trainer compared to conventional physical therapy in retraining balance in patients with type 2 DPN. 30 type 2 DPN patients aged 55-65 years, men and women, were selected from the diabetes center. Group A received balance training with stability trainer and Group B received conventional physical therapy exercises. BBS and DGI were measured on the first day (week 1) and last day (week 8) of the intervention. Pretest and posttest scores were compared and the results were tabulated. Both groups significantly improved their balance sheet. The functional balance of group A was statistically significantly improved compared to group B.³⁵

Irshad Ahmad et al (2020) investigated the effects of sensorimotor and walking training on proprioception, nerve function and muscle activation in people with DPN. 38 (25 male and 13 female) people with DPN were recruited and randomly assigned to intervention and control groups. Participants in the intervention group underwent sensory motor and gait exercises that included wall sliding, bridge exercises, sit-to-stand exercises, exercises on wobble board, one-leg stance, heel and toe raises, varying degrees of tandem stance using an unstable surface, and gait training (various gaits) for 8 weeks (3 days/week) and diabetes and foot care training; patients in the control group received training of diabetes and foot care only. Outcome measures included studies of proprioception, peroneal and tibial nerve conduction, and lower extremity muscle and multifidus activation while standing with eyes open and closed and walking on a treadmill. Analysis of the data by mixed ANOVA showed a significant time effect and a time $\times$ group interaction for proprioception in all four directions with $p < 0.05$. Peroneal nerve NCV showed a significant time effect ($p = 0.007$) and a time $\times$ group interaction ($p = 0.022$). The interaction effect was found to be significant for the medial gastrocnemius and multifidus during standing with eyes open and eyes closed with $p \leq 0.004$. Only multifidus showed a significant group ($p = 0.002$) and interaction ($p = 0.003$) during walking. They concluded that sensorimotor and gait training is an effective to improve proprioception and neural function.³⁶

Yashasree Patil et al (2021) conducted this study to investigate the effect of task-directed exercises on improving balance and reducing the fall risk in people with DN. 18 patients who met the inclusive and exclusive criteria were divided into two groups. Group A ($n=8$) received conventional physical therapy whereas Group B ($n=10$) received task-based exercises in addition to conventional physical therapy. The result of this study showed that there are significant differences in the values of both the fear of falling avoidance behavior questionnaire and the BBS scale before and after, except for the BBS A group scores, there is no significant change. In the comparison between Group A and Group B, the FFABQ and BBS scores of Group B improved more than Group A. The conclusion of this study was that task-oriented exercises combined with traditional physical therapy were more effective in improving balance and reduce fear of falling down than conventional physical therapy alone in patients with diabetic neuropathy after three weeks of treatment.³⁷

DISCUSSION

This review assessed the current evidence for exercise therapy treatment in improving balance and gait in patients with diabetic neuropathy. The aim of this review was to synthesize the role of exercise therapy in improving balance and gait in patients with diabetic neuropathy. The results of this review showed that therapeutic exercises had a beneficial effect on improving gait and balance in DN patients. All studies included in this review investigated the post-

treatment effects of exercise therapy on balance and gait function in DN patients. For example, Bina Eftekhar-Sadat²⁵ et al. study showed that a balance training program using Biodex Balance System significantly improved TUG, BBS and BBS indices, especially the fall risk in the experimental group, and can be used as a useful tool in the treatment of DN patients with postural instability and risk from falling. This improvement was due to improved proprioception and muscle strength. Ajitha M et al.³⁵ shows that exercise on stability trainer significantly improves functional balance after an 8-week exercise program compared to conventional physical therapy. In addition, Ilaria Zivi³⁹ et al. study showed that aquatic physiotherapy to improve gait and balance in patients with DPN, significantly improved DGI scores and functional ambulation classification scores compared to land-based physiotherapy. This may occur due to the high sense of stability offered by water, and its effect on pain perception and the water environment may be suitable mainly for the rehabilitation of DN patients with a high fear of falling or pain. Overall, the majority of included studies demonstrated that exercise therapy significantly improved balance and gait function in DPN patients compared to controls.

CONCLUSION

Current data indicate that exercise therapy is safe and feasible and has been found to improve balance and gait in patients with Diabetic peripheral neuropathy. Specific exercise programs, including ROM, muscle strengthening, circuit training, stretching, gait, and balance exercises can improve gait and balance in diabetics with peripheral neuropathy.

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REFERENCES

- Jannu C, Prathap S, Puchchakayala G et al. Efficacy of Stability Trainer Exercises versus Wobble Board Exercises in Balance Re-Education in Patients with Diabetic Neuropathy. *Indian J. Physiother. Occup. Ther. An. Int. J.* 2017 Jul;11 (3):12-16.
- Tomic D, Shaw, J.E. & Magliano et al The burden and risks of emerging complications of diabetes mellitus. *Nat Rev Endocrinol* 18, 525–539 (2022).
- Unnikrishnan R, Anjana, R. & Mohan V. Diabetes mellitus and its complications in India. *Nat Rev Endocrinol* 12, 2016, 357–370.
- Schreiber, A. K., Nones, C. F. et al. Diabetic neuropathic pain: Physiopathology and treatment. *World journal of diabetes*. 2015 6(3), 432–444.
- Ramachandran A. Know the signs and symptoms of diabetes. *The Indian journal of medical research*. 2014 Nov;140(5):579.
- Linda J. D'Silva, James Lin, Hinrich Staecker et al. Impact of Diabetic Complications on Balance and Falls: Contribution of the Vestibular System, *Physical Therapy*, Volume 96, Issue 3, 1 March 2016, Pages 400–409.
- Ziegler D, Papanas N, Schnell O. et al. Current concepts in the management of diabetic polyneuropathy. *Journal of Diabetes Investigation*. 2021 Apr;12(4):464-75.
- Jiang X, Deng F, Rui S, et al. The Evaluation of Gait and Balance for Patients with Early Diabetic Peripheral Neuropathy: A Cross-Sectional Study. *Risk Manag Healthc Policy*. 2022;15:543-552.
- Al-Momani M, Al-Momani F, Alghadir AH et al. Factors related to gait and balance deficits in older adults. *Clinical interventions in aging*. 2016;11:1043.
- Jesson T, Runge N, Schmid AB. Physiotherapy for people with painful peripheral neuropathies: a narrative review of its efficacy and safety. *Pain Reports*. 2020 Sep;5(5).
- Melese, H., Alamer, A., Hailu Temesgen, M. et al. Effectiveness of Exercise Therapy on Gait Function in Diabetic Peripheral Neuropathy Patients: A Systematic Review of Randomized Controlled Trials. 2020. *Diabetes, metabolic syndrome and obesity : targets and therapy*, 13, 2753–2764.
- Cadore EL, Rodríguez-Mañas L, Sinclair A, et al. Effects of different exercise interventions on risk of falls, gait ability, and balance in physically frail older adults: a systematic review. *Rejuvenation Res*. 2013;16(2):105–114.
- Alexander NB. Postural control in older adults. *Journal of the American Geriatrics Society*, 1994, 42:93–108.
- Hewston P, Deshpande N. Falls and balance impairments in older adults with type 2 diabetes: thinking beyond diabetic peripheral neuropathy. *Canadian Journal of Diabetes* 2016, 40: 6–9.
- Cirpaci, D. & Goanta, Cristina & Budu, Vlad & Tuşaliu et al. Balance disorders and diabetes mellitus - General considerations. *Archives of the Balkan Medical Union*. 52. 439-444.
- Timar B., Timar R., Gaiță L et al. The Impact of Diabetic Neuropathy on Balance and on the Risk of Falls in Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Study. *PloS one* 2016.11(4), e0154654.
- Alam U, Riley D. R, Jugdey et al. 2017. Diabetic Neuropathy and Gait: A Review. *Diabetes therapy : research, treatment and education of diabetes and related disorders*, 8(6), 1253–1264.
- Salsich GB, Mueller MJ. Effect of plantar flexor muscle stiffness on selected gait characteristics. *Gait Posture*. 2000;11:207–216.
- Brach J S, Talkowski J B, Strotmeyer E S et al. Diabetes mellitus and gait dysfunction: possible explanatory factors. *Physical therapy*. 2008; 88(11), 1365–1374.
- Timsina LR, Willetts JL, Brennan MJ et al. Circumstances of fall-related injuries by age and gender among community-dwelling adults in the United States. *PLoS One*. 2017;12(5):e0176561.
- Richardson JK, Sandman D, Vela S. A focused exercise regimen improves clinical measures of balance in patients with peripheral neuropathy. *Arch Phys Med Rehabil*. 2001; 82:205–209.
- Toftagen C, Visovsky C, Berry DL. Strength and balance training for adults with peripheral neuropathy and high risk of fall: current evidence and implications for future

- research. *InOncology nursing forum* 2012; (39) 5:416. NIH Public Access.
- Streckmann F, Zopf EM, Lehmann HC et al. Exercise intervention studies in patients with peripheral neuropathy: a systematic review. *Sports medicine*. 2014 ;44(9):1289-304.
- EL-REFAY BH, Ali OI. Efficacy of exercise rehabilitation program in improving gait of diabetic neuropathy patients. *Assessment*. 2013 Jun;2014.
- Akbari M, Jafari H, Moshashae A, Forugh B. Do diabetic neuropathy patients benefit from balance training?. *Journal of Rehabilitation Research & Development*. 2012; 49(2).
- Lee K, Lee S, Song C. Whole-body vibration training improves balance, muscle strength and glycosylated hemoglobin in elderly patients with diabetic neuropathy. *The Tohoku journal of experimental medicine*. 2013; 231(4):305-14.
- Eftekhar-Sadat B, Azizi R, Aliasgharzadeh A et al. Effect of balance training with Biodex Stability System on balance in diabetic neuropathy. *Therapeutic advances in endocrinology and metabolism*. 2015 Oct; 6(5):233-40.
- Salsabili H, Bahrpeyma F, Esteki A. The effects of Task-Oriented Motor Training on gait characteristics of patients with type 2 diabetes neuropathy. *Journal of diabetes & Metabolic disorders*. 2015 Dec;15(1):1-0.
- Kamatchi K, Divya M, Rajalaxmi V et al. Effect of proprioception training and backward walking training among diabetic neuropathy patients. *The American Journal of Drug and Alcohol Abuse*. 2018 May 25;10(1):2820-4.
- Zivi I, Maffia S, Ferrari V et al. Effectiveness of aquatic versus land physiotherapy in the treatment of peripheral neuropathies: a randomized controlled trial. *Clinical rehabilitation*. 2018 May;32(5):663-70.
- Farhan V, Abbasi A, Tabatabaei Ghomshe F et al. Effect of Combined Trainings (Rom improvement, Muscle Strengthening, Balance Training, and Gait Training) on Balance and Risk for Falling in Older Women with Diabetic Peripheral Neuropathy. *The Scientific Journal of Rehabilitation Medicine*. 2019 Jun 22;8(2):97-105.
- Maruboyina S, Atry S, Kumari BK et al. Comparison of Exercises on two Unstable Surfaces for Balance and Gait Re-education in Patients with Diabetic Peripheral Neuropathy. *JMSCR* 2018. June; 06 (06):752-756.
- Hung ES, Chen SC, Chang FC et al. Effects of interactive video game-based exercise on balance in diabetic patients with peripheral neuropathy: an open-level, Crossover Pilot Study. *Evidence-Based Complementary and Alternative Medicine*. 2019 Jan 1;2019.
- Saleh MS, Rehab NI. Effect of ankle proprioceptive training on gait and risk of fall in patients with diabetic neuropathy: A randomized controlled trial. *International Journal of Diabetes Research*. 2019 May 12;2(1):40-5.
- Ajitha M. Effectiveness of stability trainer exercises over conventional physiotherapy on balance re-education in patients with type 2 diabetic peripheral neuropathy. *International Journal of Physical Education, Sports and Health* 2020; 7(4): 90-97.
- Ahmad I, Verma S, Noohu MM et al. 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.
- Patil Y, Singaravelan RM, Borkar TP. Effects of Task-Oriented Exercises on Improving the Balance, Minimizing the Risk of Fall in Patients with Diabetic Neuropathy-A Comparative Study. *Indian Journal of Public Health Research & Development*. 2021 Oct 1;12(4).