Original Article

Effect of Yogasana Intervention on Standing Balance Performance among People with Diabetic Peripheral Neuropathy: A Pilot Study

Jinny P. Kanjirathingal, Rajani P. Mullerpatan[1], Girish Nehete, Nagarathna Raghuram[2]

Department of Musculoskeletal Physiotherapy, MGM School of Physiotherapy, MGM Institute of Health Sciences, [1]MGM Centre of Human Movement Science, MGM School of Physiotherapy, MGM Institute of Health Sciences, Navi Mumbai, Maharashtra, [2]Medical Director, Vivekanada Yoga Anusandhana Samasthana, Bengaluru, Karnataka, India

Abstract

Background: Diabetic peripheral neuropathy (DPN) is known to cause impaired balance and eventually increased risk of fall. Yogasanas characterized by slow, gentle transitions into postures with a varying base of support and focus on body awareness during movement hold potential for training balance control. Therefore, the current study aimed to evaluate effect of structured Yogasana intervention compared to conventional balance exercise on static and dynamic balance performance among people with diabetic neuropathy. **Methods**: Thirty-five people with DPN aged 42–70 years were recruited to Yogasana intervention group (n = 11), conventional balance exercises group (n = 10), and Control group (n = 14) following ethical approval. All participants were evaluated at baseline and post 12-week intervention on star excursion balance test, single-limb stance test, and center of pressure (CoP) excursion for balance performance, Modified fall efficacy scale for fear of falls and lower extremity strength using chair stand test and step-up test. **Results:** Balance performance (static and dynamic measured by star excursion balance test, single-limb stance test, and CoP excursion, lower extremity strength (using chair stand test and step-up test) demonstrated improvement and fear of fall reduced among Yogasana intervention group ($p \leq 0.05$) and conventional balance exercises group ($p \leq 0.05$) post 12-week intervention. CoP excursion increased in the control group indicating deterioration in balance performance after 12 weeks ($p \leq 0.05$). *Post hoc* comparison revealed that Yogasana intervention was marginally more effective in improving static and dynamic balance performance compared to conventional balance exercises in all variables of standing balance performance ($p \leq 0.025$). **Conclusion:** Yogasana and conventional balance exercises were effective in improving static and dynamic balance performance, lower extremity muscle strength, and reducing fear of fall among people with DPN. Yogasana intervention demonstrated marginally greater improvement in static and dynamic balance performance and lower extremity muscle strength compared to conventional exercise.

Keywords: *Conventional balance exercises, diabetic peripheral neuropathy, static and dynamic performance, Yogasana*

Introduction

Prevalence of diabetic neuropathy was 50% worldwide and 60.7% among north Indians in 2016 among people with diabetes.[1] Diabetic neuropathy commonly affects somatosensory and visual system.[2] Hence, the central nervous system receives altered signals of body orientation. Effectively, corrective and stabilizing forces by selective activation of muscles for maintaining balance are inappropriately stimulated, causing loss of balance in people with diabetic peripheral neuropathy (DPN).[3] Impaired balance predisposes to increased risk of falls and associated injuries.[4]

Moreover, associated injuries related to falls increase in the presence of diabetic peripheral neuropathy. Hip fractures are 1.5–12 times more common in people with diabetes, casting a negative influence on overall functioning and health-related quality of life.[3] Hence, preemptive balance training strategies designed to reduce the risk of falls gain paramount importance in comprehensive management of people with diabetic neuropathy.

Several therapeutic exercise strategies are known to improve balance performance among people with DPN, which include gait and balance exercises with function-oriented strengthening exercises, multisensory exercises, and dynamic stability training

How to cite this article: Kanjirathingal JP, Mullerpatan RP, Nehete G, Raghuram N. Effect of yogasana intervention on standing balance performance among people with diabetic peripheral neuropathy: A pilot study. Int J Yoga 2021;14:60-70.

Submitted: 10-Jul-2020 **Revised:** 09-Sep-2020
Accepted: 09-Dec-2020 **Published:** 05-Feb-2021

Address for correspondence:
Dr. Rajani P. Mullerpatan, MGM Centre of Human Movement Science, MGM School of Physiotherapy, MGM Institute of Health Sciences, Navi Mumbai, Maharashtra, India.
E-mail: rajani.kanade@gmail.com

Access this article online

Website: www.ijoy.org.in

DOI: 10.4103/ijoy.IJOY_75_20

Quick Response Code:

which target the proprioceptors and vestibular system with and without visual feedback.[2-8] In addition to conventional exercise program, one exploratory pilot study has reported a beneficial effect of Yoga intervention in the improvement of balance, balance confidence, and occupational performance in people with DPN using Bergs balance scale, activity-specific balance confidence scale, and Canadian occupational performance measure.[9]

Yogasanas are known to focus on positional awareness, which stimulate the vestibular system and visual feedback, after attainment of final pose.[10] Therefore, it was speculated that Yogasanas hold immense potential to emerge as a therapeutic tool to improve balance. Hence, the present study was designed to explore the effect of Yogasana intervention on static and dynamic balance performance in comparison with conventional balance exercises among people with diabetic neuropathy.

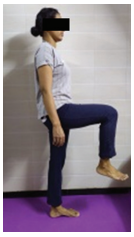
Methods

The pilot study was conducted after approval of Institutional Ethics Review Committee, MGM Institute of Health Sciences, Kamothe, Navi Mumbai at MGM Center of Human Movement Science and MGM School of Physiotherapy, Navi Mumbai. Thirty-five volunteers clinically diagnosed with DPN presenting with loss of protective sensation,[11] vibration perception threshold of ≥20 V[12] in foot, and a minimum score of 20/40 in the visual acuity test[13] within the age group of 42–70 years were recruited through purposive sampling after seeking signed informed consent. Participants with a history of foot ulcer, recent neuromusculoskeletal injury, acute cardiovascular complications (<3 months), and involvement in any form of active physical activity such as Yoga or aerobics were excluded from the study. Participants were allotted to three Groups, i.e., Yogasana intervention group, conventional balance exercises group, and controls on the basis of their availability and proximity.

Trajectory of center of pressure (CoP) excursion was evaluated using AMTI (USA) force plate (BP 400600). Analog output from force plate data (c3d file) was recorded, and excursion of CoP was computed using MATLAB (R2012b, 8.0.0.7) program.[14] Static balance

Figure 1: Conventional balance training exercises

Warm-up (5 min):



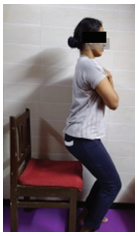
Double-legged stance for 10 seconds

Tandem stance for 10 s

Single legged stance for 10 s

Weight shifting exercise on foam pad with eyes open and eyes closed

Rising from a chair without the use of arms



Walking forwards and backwards with a tandem walking pattern

Cool down

Table 1: Protocol for 12-week Yogasana intervention

Week	Name of asana	Steps
Week 1	Vrikshasana	Single limb stance with support
	Tadasana	Bilateral heel rise with support (wide BOS)
	Padhastasana	Bending forward to reach toes
Week 2	Vrikshasana	Single limb stance with support (minimum)
	Tadasana	Bilateral heel rise (wide BOS) with support (minimum)
	Padhastasana	Bending forward to reach toes
	Virabhadrasana I	Lunge forward with support
	Virabhadrasana II	Lunge sideward with support
Week 3	Vrikshasana	Single limb stance longer duration with support (minimum)
	Tadasana	Bilateral heel rise (narrow BOS) with support
	Padhastasana	Bending forward to reach toes
	Utkatasana	Partial squats with support
	Virabhadrasana I	Lunge forward with support
Week 4	Vrikshasana	Single limb stance longer duration with support (minimum)
	Tadasana	Bilateral heel rise (narrow BOS) with support (minimum)
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with support
	Virabhadrasana I	Lunge forward with support
	Virabhadrasana II	Lunge sideward with support
Week 5	Vrikshasana	Single limb stance by placing unsupported limb on stance limb with support (minimum)
	Tadasana	Bilateral heel rise (narrow BOS) longer duration without support
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with support
	Virabhadrasana I	Lunge forward with support (minimum)
	Virabhadrasana II	Lunge sideward with support (minimum)
Week 6	Vrikshasana	Single limb stance by placing unsupported limb on stance limb with support (minimum) and hands raised sideward
	Tadasana	Bilateral heel rise (narrow BOS) longer duration without support and hands by raised sideward
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with hand raised forward with support
	Virabhadrasana I	Lunge forward without support
	Virabhadrasana II	Lunge sideward without support
Week 7	Vrikshasana	Single limb stance by placing unsupported limb on stance limb with support (minimum) and hands raised sideward
	Tadasana	Bilateral heel rise (narrow BOS) longer duration without support and hands by raised sideward
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with hand raised forward without support
	Virabhadrasana I	Lunge forward without support
	Virabhadrasana II	Lunge sideward without support
	Garudasana	Slightly bend knees, cross unsupported limb over stance limb with support, try to hook the feet behind calf
Week 8	Vrikshasana	Single limb stance by placing unsupported limb on stance limb with support (minimum) and hands raised sideward
	Tadasana	Bilateral heel rise (narrow BOS) longer duration without support and hands by raised upward
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with hand raised forward without support
	Virabhadrasana I	Lunge forward without support hands raised sideward
	Virabhadrasana II	Lunge sideward without support hands raised sideward
	Virabhadrasana III	Bend forwards extend leg with support
	Natrajasana	Single limb stance grasping unsupported limb at ankle
	Garudasana	Slightly bend knees, cross unsupported limb over stance limb with support, try to hook the feet behind calf

Contd...

Table 1: Contd...

Week	Name of asana	Steps
Week 9	Vrikshasana	Single limb stance by placing unsupported limb on stance limb with support (minimum) and hands raised sideward
	Tadasana	Bilateral heel rise (narrow BOS) longer duration without support and hands by raised upward
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with hand raised forward without support
	Virabhadrasana I	Lunge forward without support hands raised upwards
	Virabhadrasana II	Lunge sideward without support hands raised sideward
	Virabhadrasana III	Bend forwards extend leg or raise arm forward alternately with support
	Natrajasana	Single limb stance grasping unsupported limb at ankle bend forwards
	Garudasana	Cross left elbow over right and bring palm of hands together.
Week 10	Vrikshasana	Single limb stance by placing unsupported limb on stance limb with support (minimum) and hands raised sideward
	Tadasana	Bilateral heel rise (narrow BOS) longer duration without support and hands by raised upward
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with hand raised forward without support
	Virabhadrasana I	Lunge forward without support hands raised upwards
	Virabhadrasana II	Lunge sideward without support hands raised sideward
	Virabhadrasana III	Bend forwards extend leg and raise arm forward with support
	Ardhachandrasanas	Bend forwards extend leg rotate trunk raise arm sideward with support
	Natrajasana	Single limb stance grasping unsupported limb at ankle bend forwards, raise arm forwards with support
	Garudasana	Alternate between arms and legs
Week 11	Vrikshasana	Single limb stance by placing unsupported limb on stance limb with support (minimum) and hands raised sideward
	Tadasana	Bilateral heel rise (narrow BOS) longer duration without support and hands by raised upward
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with hand raised forward without support
	Virabhadrasana I	Lunge forward without support hands raised upwards
	Virabhadrasana II	Lunge sideward without support hands raised sideward
	Virabhadrasana III	Bend forwards extend leg and raise arm forward with minimum support
	Ardhachandrasanas	Bend forwards extend leg rotate trunk raise arm sideward with minimum support
	Natrajasana	Single limb stance grasping unsupported limb at ankle bend forwards, raise arm forwards with minimum support
	Garudasana	Slightly bend knees, cross unsupported limb over stance limb with support, try to hook the feet behind calf maintain this tr to cross left elbow over right and bring palm of hands together
Week 12	Vrikshasana	Single limb stance by placing unsupported limb on stance limb with support (minimum) and hands raised sideward
	Tadasana	Bilateral heel rise (narrow BOS) longer duration without support and hands by raised upward
	Padhastasana	Bending forward to reach toes and touch forehead to shin
	Utkatasana	Partial squats with hand raised forward without support
	Virabhadrasana I	Lunge forward without support hands raised upwards
	Virabhadrasana II	Lunge sideward without support hands raised sideward
	Virabhadrasana III	Bend forwards extend leg and raise arm forward without support
	Ardhachandrasanas	Bend forwards extend leg rotate trunk raise arm sideward without support
	Natrajasana	Single limb stance grasping unsupported limb at ankle bend forwards, raise arm forwards without support
	Garudasana	Slightly bend knees, cross unsupported limb over stance limb with support, try to hook the feet behind calf maintain this tr to cross left elbow over right and bring palm of hands together

BOS: Base of support

performance was evaluated in four conditions: wide base of support with eyes open and eyes closed, narrow base of support with eyes open and eyes closed.[15]

Dynamic balance performance was studied using robust clinical tools: Star Excursion Balance Test and single-limb stance test. Lower extremity strength was evaluated using 30-s chair stand test and step-up test (forward and lateral). Protocol for all the test procedures was taken from previous studies.[16-19] Three trials of each task were recorded. Outcome measures included Michigan Neuropathy Screening Instrument[20] and Modified Fall Efficacy scale.[21]

The structured Yogasana intervention for training balance performance was designed by a certified trained Yoga practitioner and expert Yoga Science researcher.

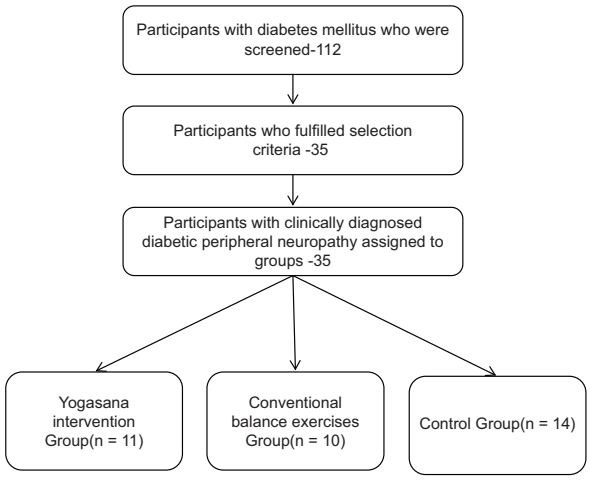


Figure 2: Recruitment of participants with diabetic peripheral neuropathy

Intervention was designed to challenge two major systems responsible for balance control, i.e., the somatosensory system (proprioceptive) and vestibular system. Yogasana intervention included Vrikshasana, Utkatasana, Padhastasana, Tadasana, Virabhadrasana I, Virabhadrasana II, Virabhadrasana III, Natrajasana, Ardhachandrasanas, and Garudasana. The Yogasana intervention included simple and difficult to perform asanas, introduced in a graded manner. Each of the asanas were progressed step wise on a weekly basis [Table 1]. Conventional balance [Figure 1] exercises were adopted from previous studies targeted to challenge somatosensory system.[2,5] Both intervention groups received training sessions thrice a week (one supervised session per week) for 1 h/session for 12 weeks. In addition, both intervention groups were advised foot care. The Yogasana training and balance exercises were performed on Yoga mat. Control group participants were advised foot care and continued their daily activities for 12 weeks. After 12 weeks, participants of all three groups were evaluated. Control group participants were offered Yogasana intervention after the study to ensure that they were not deprived of balance training therapy.

Star excursion balance test scores were normalized with leg length of the participant by dividing the test score by leg length in cm multiplied by 100. Normality of distribution was ascertained; measures of central tendency and dispersion were calculated and reported as means and standard deviation. Comparison between groups was performed using ANOVA with the level of significance at $p \leq 0.05$. *Post hoc* analysis was performed using Bonferroni test with a level of significance adjusted at $p \leq 0.025$. Within-group comparisons were done using paired *t*-test for variables of star excursion balance test and single-limb stance test with eyes closed. Variables that did not follow normal distribution were compared using nonparametric test (using Wilcoxon test and Mann–Whitney test).

Results

Figure 2 illustrates recruitment process for the study. Table 2 presents demographic characteristics and baseline clinical profile of participants. Table 3 shows results of comparisons at baseline and post 12-week balance performance, which revealed that Yogasana intervention group and conventional exercises group demonstrated greater postural stability postintervention in all three directions of star excursion balance test and single limb stance test eyes closed compared to control group ($p \leq 0.05$).

Post 12-weeks, significant difference was noted in CoP trajectory among three Groups. The control group demonstrated significantly increased values in CoP excursion on force platform indicating deterioration of balance performance over 12-week period. However, no significant difference was noted in single-limb stance test with eyes open. Chair-stand test and step-up test front and lateral revealed improved lower extremity strength in the Yogasana intervention group and conventional balance exercises group ($p \leq 0.05$). There was no significant difference ($p > 0.05$) in lower extremity strength in the control group except in the step-up test front ($p = 0.003$). Fear of falls reported by the modified fall efficacy scale demonstrated high scores over the period of 12 weeks, which indicates decrease in fear of falls in Yogasana intervention and conventional balance exercises group ($p \leq 0.05$). There was no significant difference ($p > 0.05$) in the control group.

Table 4 shows comparison of balance performance between three groups which revealed significant difference ($p \leq 0.05$) in postural stability among Yogasana intervention group and conventional balance exercise group among the all the variables of star excursion balance test, single limb stance test, and CoP. *Post hoc* comparison revealed that Yogasana intervention was more effective to improve static and dynamic performance measured by clinical outcome measures compared to conventional balance exercises.

However, there was no significant difference between Yogasana intervention group and conventional balance exercise group in bipedal balance performance. Between Yogasana intervention group and age-matched controls, significant difference was noted only with narrow base of support eyes open ($p = 0.011$) and eyes closed ($p = 0.001$). Similarly, between conventional balance exercise group and age-matched controls, a significant difference was noted only with narrow base of support eyes open ($p = 0.019$) and eyes closed ($p = 0.005$).

Lower extremity strength demonstrated by chair stand test and step-up test front and lateral improved significantly ($p \leq 0.05$) among Yogasana intervention group and conventional balance exercises group. *Post hoc* comparison between the groups revealed a significant ($p \leq 0.025$) improvement in strength in the Yogasana intervention group followed by conventional balance exercise group in the chair stand test and step-up test (front). Comparison between groups in the step-up

Table 2: Summary of demographic characteristics and baseline clinical presentation of participants

Variables	Mean (SD)		
	Yogasana intervention (*n*=11)	Conventional balance exercises (*n*=10)	Controls (*n*=14)
Demographic information			
Age (year)	55.5 (7)	58.7 (5.6)	57.7 (6)
Body mass (kg)	69.4 (1.5)	69.8 (4.4)	63.8 (7.7)
Height (m)	1.6 (0.1)	1.6 (0.1)	1 (0.9)
BMI (*n*)			
<25	4	3	12
>25	7	7	2
Duration of diabetes (year)	8 (3.2)	11.4 (3.6)	9.57 (5.24)
Fasting blood glucose (mg/dl)	143 (36.37)	192.8 (73.33)	125.3 (23.99)
Postmeal blood glucose (mg/dl)	200.8 (74.60)	230 (81.70)	167.43 (41.83)

Baseline clinical presentation						
Variables	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**
Vibration perception threshold at Hallux (V)	23.55 (3.23)	23.91 (4.18)	24.80 (5.41)	22.90 (4.01)	21.21 (9.32)	24.50 (4.80)
Vibration perception threshold at 1st MTH (V)	22.91 (4.18)	22.27 (2.64)	22 (2)	23.90 (4.40)	23.70 (8.89)	22.79 (2.45)
Vibration perception threshold at 2nd MTH (V)	22.64 (3.29)	22.55 (3.02)	23.80 (3.88)	23.70 (3.52)	22.57 (2.40)	23.79 (5.11)
Vibration perception threshold at 5th MTH (V)	22.09 (2.46)	23.27 (3.84)	24.70 (3.86)	22.80 (3.12)	23.93 (2.81)	24 (3.32)
Vibration perception threshold at Heel (V)	25.27 (2.86)	23.91 (3.78)	29.70 (10.67)	23 (0)	25.57 (3.10)	23 (0)
Variables	**Median (SD)**		**Median (SD)**		**Median (SD)**	
Touch pressure sensation scoring (five sites)	2 (0.52)	2 (0.46)	2 (0.51)	3 (0.42)	2 (0.47)	2 (0.45)
Michigan neuropathy screening instrument A	5 (0.81)		5 (0.91)		5 (1.22)	
Michigan neuropathy screening instrument B	5 (1.19)		5.75 (1.48)		5.50 (0.74)	
Visual acuity scoring	80 (2.61)	80 (2.61)	85 (1.58)	85 (2.10)	85 (1.33)	85 (0)

SD: Standard deviation

test between groups revealed improved strength in both Yogasana intervention group and conventional balance exercises group, however, no difference was noted in between conventional balance exercises group and control group.

Results of patient reported fear of falls scale revealed a significant ($p \leq 0.05$) improvement in balance confidence reported ($p \leq 0.05$) by Yogasana intervention group and conventional balance exercises group. The *Post hoc* comparison test revealed no significant difference ($p \leq 0.025$) between Yogasana intervention group and conventional balance exercises group. However, significant ($p \leq 0.05$) difference was noted between the Yogasana intervention group and control group; Conventional balance exercises group and control group.

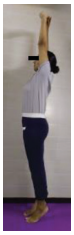
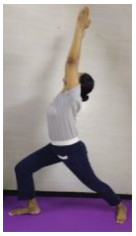
Discussion

The current study revealed that 12-week Yogasana intervention demonstrated greater improvement in variables quantifying clinical static and dynamic balance, lower extremity strength compared to conventional balance exercises among people with DPN. The Yogasana intervention group demonstrated maximum improvement in variables of static balance followed by moderate improvement in variables of dynamic balance and lower extremity strength compared to conventional exercise group. Static and dynamic balance performance deteriorated over 12-week period in the control group.

Yogasana intervention demonstrated six times greater improvement in maintenance of single limb stance (eyes open) time compared to conventional exercise group. It is speculated that structured Yogasana intervention stimulates positional awareness and vestibular system of the body. Vrikshasana, Utkatasana, Tadasana, Padhastasana, and Garudasana targeted somatosensory system through stimulation of proprioceptors by supporting the head-arm-trunk within a narrow base of support [Figure 3]. Whereas Virabhadrasana I, Virabhadrasana II and Virabhadrasana III, Natrajasana, and Ardhachandrasana included movements head–trunk–arm components in space while supporting the body over narrow base, thus challenging the somatosensory system and the vestibular system [Figure 3]. During the performance of Yogasana, the participants were instructed to maintain the asana with a focus on awareness of each body segment at every step of asana, which may have provided proprioceptive feedback to the participant.

Yogasana intervention demonstrated 60% greater improvement in dynamic balance performance quantified using clinical measure (star excursion test) compared to the conventional exercise group. Postural control was challenged by five out ten asanas, namely, Vrikshasana, Garudasana,

Figure 3: Yogasana intervention

Name of yogasana	Description	Name of yogasana	Description
Vrikshasana 	In standing pose, exhale and bend left knee and place the foot against the inside of the right thigh, with the heel abutting your groin. Inhale and raise your arms overhead and keep palms together. Repeat on other side	Utkatasana 	In standing pose, inhale and raise your arms in front of your body up to shoulder level, then exhale and bend your knees and lower your trunk to the half-squat pose without bending forwards
Padhastasana 	In standing pose, inhale and raise your arms up, slowly exhale and bend forwards completely and place the palms of your hands beneath your feet	Tadasana 	In standing pose, interlock your fingers and raise your arms overhead as you raise your heels
Virabhadrasana I 	Stand with feet apart, exhale and turn to the right while turning your right foot. Inhale, raise your arms overhead and bend back. Exhale, bend your right knee and lower your trunk. Repeat on the other side	Virabhadrasana II 	Stand with feet apart, exhale and turn your right foot. Inhale and raise your arms sideways up to shoulder level. Exhale and bend your right knee and lower your trunk. Repeat on the other side
Virabhadrasana III 	In standing pose, inhale and raise arms overhead. While exhaling bend your knees and lower your trunk. Inhale and raise left leg backward and bend forward with arms stretched overhead. Inhale and straighten the right knee. Repeat on other side	Natrajasana 	In standing pose, exhale and take hold of your right foot with your right hand and pull it behind your back. Stretch your left hand in front of you. Repeat on both sides
Ardhachandrasanas 	In standing pose, inhale and raise arms sideward. While exhaling bend your knees and lower your trunk. Inhale and raise left leg backward and bend forward. Rotate your trunk to left. Inhale and straighten the right knee. Repeat on other side	Garudasana 	In standing pose, exhale and bend your knees slightly, cross your left thigh over right. Inhale, point your left toes towards the floor and hook the forefoot behind the lower right calf. Inhale, cross your arms in front of your trunk keeping right arm on top of left arm and bend your elbow. Keep the forearm perpendicular to the floor and should palms face each other

Virabhadrasana III, Natrajasana, and Ardhachandrasanas because these are single limb poses with head–trunk–arm component supported by a small base of support over single foot to maintain standing balance. Outstretched arms while performing Vrikshasana; displace COM to the highest summit in an upright stance, thereby challenging the postural control. In addition, Virabhadrasana III, Natrajasana, and Ardhachandrasanas poses displace COM outside the small base of support while sustaining the posture. Virabhadrasana I involved stepping and shift in weight distribution, which is speculated to promote body awareness and postural control.[22] Tadasana promoted equal weight distribution through coactivation of hip flexors and extensors, ultimately improving pelvic stabilization and postural control.

Yogasana intervention demonstrated 30% greater improvement in lower extremity strength (chair stand test, forward step-up test) compared to the conventional exercise group. It is reasonable to argue that sustenance of each Yogasana posture targeted selective activation of hip and core muscle groups necessary for balance maintenance

Table 3: Comparison of baseline and post 12-weeks balance performance of people with diabetic peripheral neuropathy using paired *t*-test test

Variables	Mean (SD)								
	Yogasana intervention (*n*=11)			Conventional balance exercises (*n*=10)			Controls (*n*=14)		
	Pre	Post	*p* (*p*≤0.05)	Pre	Post	*p* (*p*≤0.05)	Pre	Post	*p* (*p*≤0.05)
Star excursion balance test (paired *t*-test)									
Anterior R (cm)	68.1 (3.4)	80.1 (5.4)	0.000*	63.8 (4.4)	70.0 (4.3)	0.000*	61.1 (4.1)	61.1 (4.0)	0.725
Anterior L (cm)	67.5 (3.6)	80.6 (5.2)	0.000*	64.2 (4.4)	70.1 (4.0)	0.000*	61.7 (3)	61.3 (3)	0.035*
Postero-lateral R (cm)	68.1 (2.0)	79.2 (4)	0.000*	64.9 (5.67)	70.1 (6.87)	0.000*	63.9 (4.4)	63.7 (4.6)	0.143
Postero-lateral L (cm)	67.6 (3.4)	79.5 (4.2)	0.000*	65.1 (6.8)	70.8 (7)	0.000*	64.2 (4.9)	63.9 (4.8)	0.107
Postero-medial R (cm)	59.3 (3.3)	67.3 (3.1)	0.000*	57.4 (6.0)	61.3 (6)	0.000*	55.1 (3.6)	54.9 (3.4)	0.328
Postero-medial L (cm)	59.3 (3.4)	67.2 (3.5)	0.000*	57.9 (6.3)	61.2 (6.32)	0.002*	55.2 (3.3)	55 (4)	0.064
Single limb stance test (paired *t*-test)									
Eyes close R (s)	3.5 (1.4)	11 (3.2)	0.000*	4.4 (2.5)	7.4 (2.7)	0.000*	4.2 (0.8)	4.3 (0.9)	0.200
Eyes close L (s)	3.6 (1.3)	11.4 (3.4)	0.000*	4.3 (2.2)	8.1 (4.3)	0.016*	4.3 (0.7)	4.3 (0.7)	0.264
Single limb stance test (Wilcoxon *t*-test)									
Eyes open R (s)	17.7 (4.0)	49.7 (22.5)	0.003*	15.7 (7.5)	20.5 (7.5)	0.005*	14.9 (5.4)	14.9 (5.5)	0.666
Eyes open L (s)	17.4 (4.3)	50.3 (22.1)	0.003*	17.3 (8.4)	22.1 (7.9)	0.005*	15.0 (4.8)	15 (4.7)	0.594
Center of pressure (paired *t*-test)									
WBOSEO (s)	2.3 (0.2)	2.1 (0.2)	0.000*	2.4 (0.1)	2.2 (0.2)	0.003*	2.53 (0.3)	2.59 (0.3)	0.000*
WBOSEC (s)	2.3 (0.2)	2.2 (0.2)	0.000*	2.4 (0.3)	2.2 (0.3)	0.000*	2.5 (0.3)	2.6 (0.3)	0.000*
NBOSEO (s)	2.3 (0.3)	2.2 (0.3)	0.000*	2.4 (0.3)	2.2 (0.2)	0.000*	2.6 (0.3)	2.7 (0.3)	0.000*
NBOSEC (s)	2.4 (0.2)	2.2 (0.3)	0.000*	2.5 (0.3)	2.3 (0.3)	0.000*	2.8 (0.4)	2.9 (0.4)	0.000*
Lower extremity strength test (paired *t*-test)									
Chair stand test (number of repetitions)	9 (1.2)	12 (1.8)	0.000*	8 (1.4)	10 (1.6)	0.000*	8 (1.1)	7.7 (1.2)	0.355
Step-up test front (number of repetitions)	8 (1.2)	11.3 (1.4)	0.000*	7 (1.8)	9.3 (1.9)	0.000*	9.5 (1)	9 (1.2)	0.003*
Step-up test lateral R (number of repetitions)	8 (1.5)	10.2 (2.7)	0.000*	8 (1.9)	9.6 (1.7)	0.000*	8 (1.2)	7.9 (0.9)	0.671
Step-up test lateral L (number of repetitions)	9 (1.4)	10.7 (2.7)	0.000*	8 (1.6)	9.7 (1.8)	0.000*	9 (1.4)	8.2 (1.3)	0.055
Modified fall efficacy scale (Wilcoxon test)									
Modified fall efficacy scale	6 (0.66)	8.02 (0.39)	0.003*	6.28 (0.32)	7.60 (0.63)	0.005*	6.38 (0.9)	6.2 (0.9)	0.317

SD: Standard deviation, R: Right, L: Left *: p≤ 0.05

and ultimately resulted in improved lower extremity muscle strength-endurance. Vrikshasana, Garudasana, Virabhadrasana III, Natrajasana, and Ardhachandrasanas are single-legged poses, wherein the head, arm, and trunk components are supported on stance extremity. Body support on a single limb recruits three major antigravity muscles of the lower extremity, namely, hip extensors, knee extensors, and ankle plantar flexor to prevent vertical collapse of body towards gravity.[23] In addition, Garudasana and Utkatasana involve lowering of the upper body toward gravity eliciting eccentric muscle activity of hip, knee extensors, and ankle plantar flexors.[24] Whereas Virabhadrasana III, Natrajasana, and Ardhachandrasanas poses require the swing extremity and the trunk to remain parallel to the floor demanding recruitment of quadriceps, gluteal muscles, core muscles, and abductors of the opposite extremity, resulting in improved strength of these muscles.

Improvement in lower extremity muscle strength is known to improve balance.[8] Such positive effects of Yogasana to improve postural control, mobility, and gait speed are already reported among elderly people.[10] Previous studies have reported the activation of specific muscles during specific asanas, resulting in improved muscle strength.[22]

Out of ten standing asanas, Padhastasana and Virabhadrasana I are reported to improve flexibility of hamstrings, quadriceps, and adductor.[22] Whereas Virabhadrasana III, Natrajasana, and Ardhachandrasanas assume body into a T over the supported

Table 4: Comparison of balance performance in people with diabetic peripheral neuropathy among the three Groups using One Way ANOVA test and *post hoc* Bonferroni test

Variables	Post			*P* (*P*≤0.05)	*Post hoc* Bonferroni (*P*≤0.25)		
	Yogasana intervention Mean (SD) (*n*=11)	Conventional balance exercises Mean (SD) (*n*=10)	Controls Mean (SD) (*n*=14)		Yogasana intervention v/s Conventional balance exercises	Yogasana intervention v/s Controls	Conventional balance exercises v/s Controls
Star excursion balance test (One way Anova test)							
Anterior R (cm)	80.1 (5.4)	70.0 (4.3)	61.1 (4.0)	0.000*	0.000**	0.000**	0.000**
Anterior L (cm)	80.6 (5.2)	70.1 (4.0)	61.3 (3)	0.000*	0.000**	0.000**	0.000**
Postero-lateral R (cm)	79.2 (4)	70.1 (6.87)	63.7 (4.6)	0.000*	0.001**	0.000**	0.017*
Postero-lateral L (cm)	79.5 (4.2)	70.8 (7)	63.9 (4.8)	0.000*	0.002**	0.000**	0.12
Postero-medial R (cm)	67.3 (3.1)	61.3 (6)	54.9 (3.4)	0.000*	0.008**	0.003**	0.003**
Postero-medial L (cm)	67.2 (3.5)	61.2 (6.32)	55 (4)	0.000*	0.012**	0.000**	0.006**
Single limb stance test (one way Anova test)							
Eyes close R (sec)	11 (3.2)	7.4 (2.7)	4.3 (0.9)	0.000*	0.004**	0.000**	0.011**
Eyes close L (sec)	11.4 (3.4)	8.1 (4.3)	4.3 (0.7)	0.000*	0.047	0.000**	0.017**
(Kruskal Wallis test)					**(Mann Whitney test)**		
Eyes open R (sec)	49.7 (22.5)	20.5 (7.5)	14.9 (5.5)	0.000*	0.001*	0.000**	0.101
Eyes open L (sec)	50.3 (22.1)	22.1 (7.9)	15 (4.7)	0.000*	0.002*	0.000**	0.046
Center of Pressure (one way Anova test)							
WBOSEO (sec)	2.1 (0.2)	2.2 (0.2)	2.5 (0.3)	0.016*	1.000	0.015**	0.111
WBOSEC (sec)	2.2 (0.2)	2.2 (0.3)	2.6 (0.3)	0.031*	1.000	0.038	0.100
NBOSEO (sec)	2.2 (0.3)	2.2 (0.2)	2.7 (0.3)	0.007*	1.000	0.011**	0.019**
NBOSEC (sec)	2.2 (0.3)	2.3 (0.3)	2.9 (0.4)	0.001*	1.000	0.001**	0.005**
Lower extremity strength test (paired *t*-test)							
Chair stand test (no. of repetitions)	12 (1.8)	10 (1.6)	8 (1.2)	0.000*	0.016**	0.000**	0.003*
Step-up test Front (no. of repetitions)	11.3 (1.4)	9.3 (1.9)	9 (1.2)	0.001*	0.010**	0.001**	1.000
Step-up test Lateral R (no. of repetitions)	10.2 (2.7)	9.6 (1.7)	8 (0.9)	0.010*	1.000	0.012**	0.114
Step-up test Lateral L (no. of repetitions)	10.7 (2.7)	9.7 (1.8)	8 (1.3)	0.012*	0.738	0.011**	0.242
Modified fall efficacy scale (Kruskal Wallis test) (Mann Whitney test)							
Modified fall efficacy scale	8.02 (0.39)	8.02 (0.39)	8.02 (0.39)	0.000*	0.197	0.000**	0.000**

P for *post hoc* analysis was adjusted to 0.025. **P*≤0.05, ***P*≤0.025 SD: Standard deviation, R: Right, L: Left

limb causing lengthening of hamstrings and gastrocnemius of stance extremity. In addition, Natrajasana stretched quadriceps muscle on the opposite limb.

Participants reported 25% improved balance confidence with Yogasana intervention compared to conventional exercise group. Improved balance confidence can be attributed to effects of Yogasana on neuromusculoskeletal system among people with DPN. The selected asanas worked specifically on muscle strength, flexibility, and postural awareness engaging large muscles of the lower extremity, leading to improved postural control and reduced fear of falls post Yogasana intervention compared to controls. Improvement in balance confidence is expected to cast a positive influence on function and active participation in daily life activities. However, it was beyond the scope of this study to measure the effect of each Yogasana on static and dynamic performance.

Conventional balance exercises included in this study were targeted to enhance the afferent pathways of proprioception. The results revealed improvement in balance post 12 weeks of balance training, i.e., star excursion balance test scores and the single-limb stance test. This was because of the stimulation of the proprioceptors and improvement in lower extremity muscle strength. The results of the present study were consistent with earlier studies which reported effects of multisensory training to improve balance.[2,5,7] However, conventional exercises in the current study did not alter the somatosensory inputs (alteration of surfaces) to demonstrate improvement in balance as reported in previous studies. Recruitment of lower extremity muscles while performing the conventional balance exercises could be attributed to improved lower extremity strength demonstrated among the conventional group. Fear of falls measured by the modified fall efficacy scale was found to be reduced post-conventional balance exercise program compared to controls as the participants developed better balance confidence with exercise training. Conventional balance training targeted proprioception and visual system which are key components influencing balance and thus improving balance confidence.[25]

It was observed that the Control group deteriorated in standing balance performance over the period of 12 weeks. Lack of physical activity could be a major factor for the deterioration of balance performance in the control group. The physical activity intervention in Yogasana intervention group and conventional balance exercises group was effective in stimulation of positional awareness and muscle strength, which caused improvement in balance even with progression of symptoms in DPN which was treated medically.

CoP trajectory is a sensitive tool that measures postural stability by detecting slightest change in postural sway.[26] However, in the present study, CoP trajectory was not significantly different between Yogasana intervention and conventional balance exercises. Postural stability requires continuous sensory and motor feedback.[27] In patients with compromised somatosensory feedback like in peripheral diabetic neuropathy, peripheral sensory and motor function is substantially affected ankle and foot bilaterally.[27] Therefore, patients with diabetic neuropathy demonstrate a significant change in the dependence of ankle to hip strategies while performing static balance tasks.[27] As a result, the CoP trajectory may not be sensitive to detect postural stability resulting from altered postural strategy adapted by the patients. Recent findings have raised the possibility that biomechanical measures of postural stability may not be suitable to detect subtle changes in postural control. Thus, the authors speculate that, CoP trajectory indicated the postural control strategy rather than the influence of the strategy on balance performance and therefore CoP trajectory did not detect the changes in postural control.

Participants were marginally distributed on age, body weight, and height among Yogasana intervention group, conventional balance exercise group, and controls with DPN to rule out the confounding influence of age and body mass index on static and dynamic performance in people with DPN.[28] The number of females and males in Yogasana intervention group (five females and six males), Conventional balance exercise group (three females and seven males) and control group (ten females and four males) varied. Therefore, it was not possible to elucidate the influence of gender on balance performance in the present study.

The present study was a single-blinded study due to which there is a risk of bias. Proprioception and vestibular assessment were not measured to check the effects of intervention on these systems affecting balance.

Future studies incorporating center of mass excursion along with CoP excursion are necessary to investigate balance performance. Secondly, further, studies with larger sample size would be beneficial to check the effects of Yoga intervention with long-term follow-up.

Conclusion

Yogasana and conventional balance exercises were effective in improving static and dynamic balance performance, lower extremity muscle strength, and reducing fear of fall among people with DPN. Yogasana intervention demonstrated marginally greater improvement in static and dynamic balance performance and lower extremity muscle strength compared to conventional exercise. Whereas people with DPN in control group demonstrated deterioration of balance performance after 12 weeks.

Ethical clearance

Ethical clearance was received from the Institutional Ethics review committee, MGM Institute of Health Science, Kamothe, Navi Mumbai.

Financial support and sponsorship

This study was financially supported by MGM School of Physiotherapy, MGM Institute of Health Sciences, Navi Mumbai, India.

Conflicts of interest

There are no conflicts of interest.

References

1. Rai O, Mishra V, Chandra R, Saxena S, Mangal B. Diabetic peripheral neuropathy and its metabolic determinants in a north Indian population. Natl J Integr Res Med 2016;7:1-4.
2. Shah C. Effects of sensory training over two different surfaces on balance and gait in persons with diabetic neuropathy. Int J Recent Sci Res 2016;7:9285-90.
3. Wallace C, Reiber GE, LeMaster J, Smith DG, Sullivan K, Hayes S, *et al*. Incidence of falls, risk factors for falls, and fall-related fractures in individuals with diabetes and a prior foot ulcer. Diabetes Care 2002;25:1983-6.
4. Rojhani-Shirazi Z, Barzintaj F, Salimifard MR. Comparison the effects of two types of therapeutic exercises Frenkele versus Swiss ball on the clinical balance measures in patients with type II diabetic neuropathy. Diabetes Meta Synd: Clin Res Rev 2017;11:S29-32.
5. 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;82:205-9.
6. Allet L, Armand S, De Bie RA, Golay A, Monnin D, Aminian K, *et al*. The gait and balance of patients with diabetes can be improved: A randomised controlled trial. Diabetologia 2010;53:458-66.
7. Misha PM, Velmurugan G. Effects of multisensory exercises on improving physical function and reducing number of falls in subjects with diabetic neuropathy. IJMAES 2017;3:367-78.
8. Salsabili H, Forogh B, Rajabali S. Dynamic stability training improves standing balance control in neuropathic patients with type 2 diabetes. J Rehabil Res Dev 2011;48:775.
9. Willis Boslego LA, Munterfering Phillips CE, Atler KE, Tracy BL, Van Puymbroeck M, Schmid AA. Impact of yoga on balance, balance confidence and occupational performance for adults with diabetic peripheral neuropathy: A pilot study. Br J Occup Ther 2017;80:155-62.
10. Kelley KK, Aaron D, Hynds K, Machado E, Wolff M. The

effects of a therapeutic yoga program on postural control, mobility, and gait speed in community-dwelling older adults. J Altern Complement Med 2014;20:949-54.
11. Feng Y, Schlösser FJ, Sumpio BE. The Semmes Weinstein monofilament examination as a screening tool for diabetic peripheral neuropathy. J Vasc Surg 2009;50:675-82.
12. Bansal D, Gudala K, Muthyala H, Esam HP, Nayakallu R, Bhansali A. Prevalence and risk factors of development of peripheral diabetic neuropathy in type 2 diabetes mellitus in a tertiary care setting. J Diabetes Investig 2014;5:714-21.
13. Lovie-Kitchin JE. Validity and reliability of visual acuity measurements. Ophthalmic and physiological optics 1988;8:363-70.
14. Duarte M, Sandra MS. Revision of posturography based on force plate for balance evaluation. Rev Bras Fisioter São Carlos 2010;14:183-92.
15. Mancini M, Horak FB. The relevance of clinical balance assessment tools to differentiate balance deficits. Eur J Phys Rehabil Med 2010;46:239-48.
16. Plisky PJ, Gorman PP, Butler RJ, Kiesel KB, Underwood FB, Elkins B. The reliability of an instrumenvted device for measuring components of the star excursion balance test. North American journal of sports physical therapy: NAJSPT 2009;4:922.
17. Springer BA, Marin R, Cyhan T, Roberts H, Gill NW. Normative values for the unipedal stance test with eyes open and closed. J Geriatr Phys Ther 2007;30:8-15.
18. Jones CJ, Rikli RE, Beam WC. A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. Res Q Exerc Sport 1999;70:113-9.
19. King A, Hancock M, Munn J. The reliability of the lateral step test. J Sport Rehabil 2007;16:131-42.
20. Xiong Q, Lu B, Ye H, Wu X, Zhang T, Li Y. The diagnostic value of neuropathy symptom and change score, neuropathy impairment score and Michigan neuropathy screening instrument for diabetic peripheral neuropathy. Eur Neurol 2015;74:323-7.
21. Hill KD, Schwarz JA, Kalogeropoulos AJ, Gibson SJ. Fear of falling revisited. Arch Phys Med Rehabil 1996;77:1025-9.
22. Wang MY, Sean SY, Hashish R, Samarawickrame SD, Kazadi L, Greendale GA, *et al*. The biomechanical demands of standing yoga poses in seniors: The yoga empowers seniors study (YESS). BMC Complement Altern Med 2013;13:8.
23. Yu SS, Wang MY, Samarawickrame S, Hashish R, Kazadi L, Greendale GA, *et al*. The physical demands of the tree (Vriksasana) and one-leg balance (Utthita Hasta Padangusthasana) poses performed by seniors: A biomechanical examination. Evid Based Complement Alternat Med 2012;2012: 10.1155/2012/971896.
24. Kelley K, Slattery K, Apollo K. An electromyographic analysis of selected asana in experienced yogic practitioners. J Bodyw Move Ther 2017;22:152-8.
25. Gusi N, Adsuar JC, Corzo H, del Pozo-Cruz B, Olivares PR, Parraca JA. Balance training reduces fear of falling and improves dynamic balance and isometric strength in institutionalised older people: A randomised trial. J Physiother 2012;58:97-104.
26. Moghadam M, Ashayeri H, Salavati M, Sarafzadeh J, Taghipoor KD, Saeedi A, *et al*. Reliability of center of pressure measures of postural stability in healthy older adults: Effects of postural task difficulty and cognitive load. Gait Posture 2011;33:651-5.
27. Gladish JR, Powell DW, Allison LE, Queen RM. Center of pressure profiles in unilateral compared to bilateral end-stage ankle osteoarthritis patients. J Orthop Res 2017;35:2749-54.
28. Popescu S, Timar B, Baderca F, Simu M, Diaconu L, Velea I, *et al*. Age as an independent factor for the development of neuropathy in diabetic patients. Clin Interv Aging 2016;11:313.