Postural sway in diabetic peripheral neuropathy among Indian elderly

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Background & objectives: Diabetic peripheral neuropathy (DPN) is a major complication of type 2 diabetes and have long term complications on the postural control of the affected population. The objectives of this study were to evaluate postural stability in patients with DPN and to examine correlation of Michigan Neuropathy Screening Instrument (MNSI) with duration of diabetes, age and postural stability measures.

Methods: Participants were included if they had clinical neuropathy which was defined by MNSI. Sixty one patients gave their consent to participate in the study and were evaluated on posturography for postural stability measures in four conditions. Repeated measures of analysis of variance (RANOVA) was used to analyze the changes in postural stability measures in different conditions.

Results: An increase in mean value of postural stability measures was observed for velocity moment 20.4±1.3, 24.3±2.2, 42.3±20.7, 59±43.03, mediolateral displacement 0.21±0.10, 0.22±0.18, 0.03±0.11, 0.34±0.18, and anteroposterior displacement 0.39 ± 0.09, 0.45±0.12, 0.47±0.13, 0.51±0.20 from EO to EC, EOF, and ECF, respectively. There was a significant difference ($P<0.05$) in participants with DPN, with greater sway amplitude on firm and foam surface in all the conditions. Moderate correlation of MNSI with age (r=0.43) and postural stability measures were also observed.

Interpretation & conclusions: Evaluation of postural stability in Indian DPN population suggests balance impairments on either firm and foam surfaces, with greater likelihood of fall being on foam or deformable surfaces among elderly adults with neuropathy (CTRI/2011/07/001884).

Key words Ankle proprioception - postural instability - posturography - type 2 diabetes

Diabetes is growing at an alarming pace in India. India was home to more than 65 million people with the disease in 2013, compared to 50.8 million in 2010[1]. In an update for 2012 by International Diabetic Federation (IDF) it was found that more than 371 million people had diabetes and the number is expected to increase worldwide[2].

There are various risk factors contributing to type 2 diabetes globally[3,4]. Diabetes is associated with the risk of developing neuropathy and the incidence of neuropathy increases with the duration of the diabetes[1]. Diabetic peripheral neuropathy (DPN) is one of the common complications of diabetes which

affects almost 30-50 per cent of the population with diabetes[3]. The Fremantle Diabetes Study in 2005 after a follow up of five years found that the risk of mobility impairment was significantly increased by older age (6%/year), peripheral neuropathy (40% increase) and stroke history (123%)[5].

Diabetic foot problem is one of the most ignored aspects of diabetes care in India[6]. Due to social, religious, and economic obligations, many people with foot problems walk barefoot[7]. This can lead to early foot injuries and falls with pre-existing balance impairments.

DPN primarily confines to the small or large fiber afferent-efferent axons[4]. Usually cutaneous and proprioceptive sensations diminish, leading to reduced ankle position sense[8]. Eventually an individual suffers from impaired balance or increased risk of falls on firm and deformable surfaces in addition to pain in legs[9,10]. Previous studies have also revealed that postural instability is significantly associated with DPN[11,12].

The Michigan Neuropathy Screening Instrument (MNSI) is a useful screening test for the diagnosis of diabetic peripheral neuropathy. It is relatively simple to be used in a clinical scenario and is also reported to have a sensitivity of 79 per cent and specificity of 65 per cent in the diagnosis of DPN[12]. There is scaricity of data available from patients with DPN from India. On evaluating balance impairment in firm and foam surfaces that are commonly encountered in day to day living. Hence the primary objectives of the present study was to evaluate postural stability during quiet static stance in participants with DPN and secondary objective was to examine correlation of MNSI with duration of diabetes, age and postural stability variables in eyes open (EO), eyes closed (EC), eyes open on foam (EOF), eyes closed on foam (ECF) conditions.

Material & Methods

This cross-sectional study was performed in the department of Physiotherapy, Manipal College of Allied Health Sciences, Manipal, a tertiary care hospital in Karnataka, India. Participants were recruited from the hospital outpatient clinic from June 2010 to June 2011. The study procedure is described in detail in the Figure. The study population consisted of participants with type 2 diabetes having clinical neuropathy on examination. Ethical clearance for the study was obtained from Manipal University ethics committee and written informed consents were obtained from all the participants.

Participants with diabetes were screened for DPN using MNSI. The sums of scores varying from 0 to 1 for each abnormality as revealed in foot appearance, ulceration, ankle reflexes and vibration perception were taken into account during evaluation[13,14]. The participants were included if they had clinical neuropathy which was defined as a score of 2 out of 10 on MNSI[13]. Participants were excluded if they were found to have vitamin B12 deficiency (as it may cause symptoms that may be reversible with B12 supplementation alone), thyroid deficiency (may cause absence of ankle jerks), postural hypotension, part or complete foot amputation, vision impairments, neurological or musculoskeletal impairments, acute sciatica (pain may inhibit reflexes and muscle power in the lower limbs in sciatica leading to sway) and cognitive impairments. Vestibular dysfunction was also ruled out before their participation as vestibular impairments may also cause postural sway which might be enhanced in the presence of DPN (a total of n=7). Subjective examination and the clinical vestibular examination were performed to detect vestibular deficits using the head thrust sign. High-acceleration head thrusts were given while the patient was asked to maintain gaze on the examiner. During this maneuver, a "catch up" saccade was observed in all the patients with neuropathy while the head was rapidly turned toward the lesioned side. A total of 274 potential participants with clinical neuropathy were screened, of whom only 61 participants consented to take part in the study.

Outcome measures: Metitur good balance system was used to evaluate the postural stability under four conditions in quiet static standing: eyes open (EO), eyes closed (EC), eyes open on foam (EOF) and eyes closed on foam (ECF). Other variables taken for analysis were age and duration of diabetes.

Data collection: The participants were asked to stand quietly on the force platform with both feet in static stance and at pelvis width while measurements were recorded. Static posturography was carried out by placing the patient in a standing posture on a fixed instrumented platform (force-plate) connected to sensitive detectors (force and movement transducers), which were able to detect the tiny oscillations of the body. Thus, the posturography test protocols generate
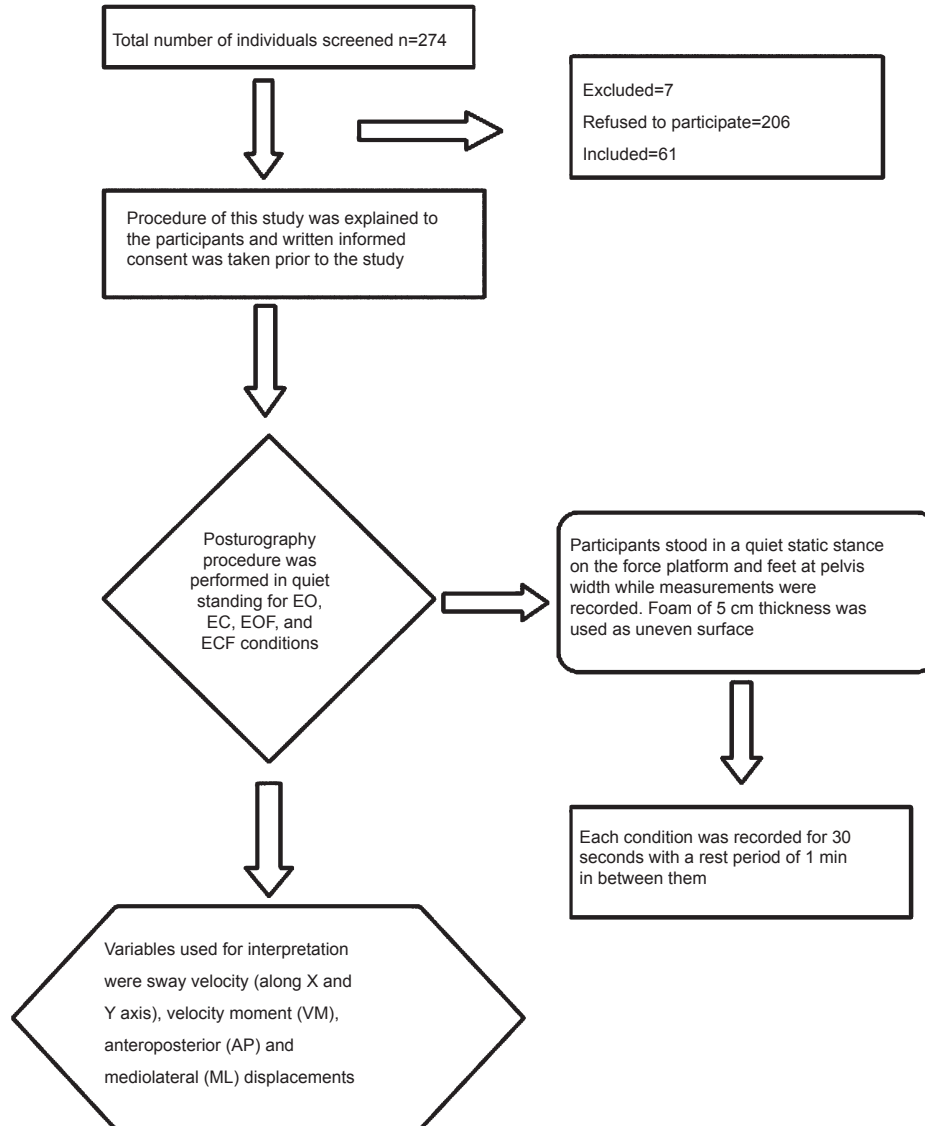
Figure. Schematic diagram showing the enrollment of the participants and the study precedure. EO, eyes open; EC, eyes closed; EOF, eyes open on foam; ECF, eyes closed on foam.

a sequence of standardized motions in the support platform to detect the degree of disequilibrium in the patient's posture in an orderly and reproducible way[14].

Metitur Good Balance system 2006 (Metitur Ltd., Jyvaskyla, Finland) was used for this study. It has a force plate which is in regular triangle shape with a side length of 800 mm and a height of 90 mm. The calibration of the force platforms was checked regularly weekly and before each day start of measuring the postural sway. The Good Balance software was used for the analysis of the transmitted information from the force plate. Participants were given fixed points on the force platform where they were required to maintain erect posture, bare feet in all conditions.

The participants were instructed to look straight with head erect and arms crossed on posturography machine to ensure correct posture while recordings were made. For all participants, data were collected for four conditions EO, EC, EOF, ECF. Each condition was recorded for 30 sec with a minute rest between them.

Foam of 5 cm thickness was used as an uneven surface for the participants in the study. Postural stability measures taken into account were sway velocity (along X and Y axis), velocity moment (VM), anteroposterior (AP) and mediolateral (ML) displacements.

The glycosylated haemoglobin (HbA1c) was analyzed using variant II turbo hemoglobin A1c programme USA which utilizes principles of ion-exchange using high-performance liquid chromatography (HPLC). The absorbance was measured at 415 nm. An additional filter was provided at 690 nm to correct the background absorbance.

Statistical analysis: Continuous variables were summarized using mean and standard deviation for demographic variables (age and duration); sway amplitudes, VM, ML and AP displacements for all the conditions. As multiple measurements were taken from the same participant in different positions, repeated measures of analysis of variance (RANOVA) was used to analyze the change in postural stability measures in different conditions. RANOVA compared the average score at multiple time periods in different conditions. Interaction effects of eyes open and closed on firm and foam surfaces were tested using SPSS 15 (SPSS Inc; Chicago, IL, USA). In order to test the hypothesis in patients under four different conditions, the power of the test for each condition was reported using RANOVA statistics. As Mauchly's test of sphericity was violated, we interpreted the results for the greenhouse-geisser correction factor for all the measurements. For primary outcome measures in the study degrees of freedom (df1, df2), F and *P* values were reported in RANOVA statistics. Pearson correlation coefficient was used to examine association between duration of diabetes, MNSI and postural stability measures.

Results

Baseline characteristics of the participants are presented in Table I. In the present study 61 participants with DPN were evaluated. There were 18 women and 43 men with a mean age of 60.38 ± 8.5 yr. Male participants in the study had a mean age of 62.3 ± 8.84 yr with mean duration of diabetes of 12.1 ± 9.08 yr. The male participants had a mean MNSI score of 4.4 ± 1.76. The female participants had a mean age of 56.1 ± 5.99 yr with mean duration of diabetes of 8.48 ± 6.37 yr and MNSI score of 2.99 ± 1.22.

There was a linear increase in the mean value of postural stability measures (sway speed, velocity moment, and mediolateral and anteroposterior displacements) from EO to EC, EOF, and ECF (Tables II-IV). Participants with neuropathy showed a significant ($P<0.5$) increase in sway velocity along the X axis for a firm surface with gender, whereas the sway velocity along the X axis on the foam surface and MNSI was insignificant. Sway velocity along the Y axis had a significant ($P<0.05$) increase for firm surface and foam surface (x) age.

Velocity moment had a significant ($P<0.05$) increase across firm surface and gender. On foam

Table I. Baseline details of the participants in the study (n=61)

Variables	Value
Height (m)	1.62 ± 0.1
Systolic blood pressure (mm Hg)	130.7 ± 13.92
Diastolic blood pressure (mm Hg)	83.46 ± 9.85
Vitamin B_{12} levels (pg/ml)	336 ± 118

Table II. Mean and standard deviation for postural stability variables in individuals with diabetic peripheral neuropathy (DPN) in four conditions (n=61)

Conditions/ Variables	EO	EC	EOF	ECF	*F*	*P*	Observed power (%)
X	4.9 ± 2.1	4.9 ± 2.7	8 ± 2.8	9.3 ± 5.7	15.79	< 0.001	99
Y	8.1 ± 2.5	10.8 ± 3.9	10.8 ± 3.4	14.1 ± 6.1	23.45	< 0.001	100
VM	20.4 ± 1.3	24.3 ± 2.2	42.3 ± 20.7	59 ± 43.03	17.06	< 0.001	100
AP	0.39 ± 0.09	0.45 ± 0.12	0.47 ± 0.13	0.51 ± 0.20	6.49	0.002	67
ML	0.21 ± 0.10	0.22 ± 0.18	0.03 ± 0.11	0.34 ± 0.18	4.22	0.02	89

EO, eyes open on firm surface; EC, eyes closed on firm surface; EOF, eyes open on foam; ECF, eyes closed on foam. X and Y- sway velocity along X and Y axis (mm/sec^2), VM, velocity moment (mm/sec^2); AP, anteroposterior displacement (mm); ML, mediolateral displacement (mm)

Table III. Mean and standard deviation for sway amplitude, velocity moment and AP and ML displacements of male individuals (n=43) with diabetic pheripheral neuropathy (DPN)

Conditions/ Variables	X	Y	VM	AP	ML
EO	4.7 ± 1.98	8.1 ± 2.59	19.22 ± 11.1	0.38 ± 0.09	0.21 ± 0.10
EC	5.19 ± 3.03	11 ± 4.09	26.78 ± 2.58	0.45 ± 0.14	0.24 ± 0.2
EOF	8.46 ± 2.87	11.23 ± 3.51	45.06 ± 21.21	0.48 ± 0.14	0.35 ± 0.13
ECF	10.42 ± 5.92	14.30 ± 5.73	69.23 ± 44.73	0.53 ± 0.20	0.38 ± 0.18

EO, eyes open on firm surface; EC, eyes closed on firm surface; EOF, eyes open on foam; ECF, eyes closed on foam. X and Y- swayvelocity along X and Y axis (mm/sec^2), VM, velocity moment (mm/sec^2); AP, anteroposterior displacement (mm); ML, mediolateral displacement (mm)

Table IV. Mean and standard deviation for sway amplitude, velocity moment and displacements of female participants (n=18) with diabetic peripheral neuropathy (DPN)

Conditions/Variables	X	Y	VM	AP	ML
E O	5.3 ± 2.43	8.42 ± 2.54	23.18 ± 1.46	0.41 ± 0.09	0.22 ± 0.11
EC	4.4 ± 2.18	10.52 ± 3.8	18.86 ± 1.24	0.45 ± 0.10	0.19 ± 0.14
EOF	7.17 ± 2.69	10.12 ± 3.2	37.07 ± 19.11	0.44 ± 0.11	0.29 ± 0.08
ECF	7.38 ± 4.9	13.74 ± 7.18	37.94 ± 30.81	0.46 ± 0.22	0.26 ± 0.18

EO, eyes open on firm surface; EC, eyes closed on firm surface; EOF, eyes open on foam; ECF, eyes closed on foam. X and Y- sway velocity along X and Y axis (mm/sec^2), VM, velocity moment (mm/sec^2); AP, anteroposterior displacement (mm); ML, mediolateral displacement (mm)

surface velocity moment had a significant ($P<0.05$) increase with duration of diabetes, MNSI and gender. A combined main effect of VM was seen with firm and foam surfaces and duration ($P<0.05$) and with firm and foam surfaces and age ($P<0.01$), respectively. In mediolateral direction there was a significant increase with firm surface and MNSI ($P<0.05$) and firm surface and gender ($P<0.05$), implying a greater postural impairments with increasing age.

A significant ($P<0.05$) increase for ML displacement across firm surface and foam surface and duration was observed and similar main effects were observed for firm surface and foam surface and MNSI. Postural impairments in the anteroposterior direction increased significantly ($P<0.01$) for firm surface and MNSI and firm surface and gender ($P<0.05$).

Correlation measures of MNSI with postural stability measures are shown in Table V. A moderate correlation ($r = 0.43$) of MNSI with age was also found whereas no correlation was found between MNSI and duration of diabetes ($r = 0.119$) in the study.

Discussion

This study suggested that measures of postural stability were impaired in participants with neuropathy and it further worsened when vision was occluded. A possible reason for it could be diminished peripheral sensations in diabetes resulting in balance impairments which usually aggravates with eyes closed[15]. These findings were in agreement with the study done by Cavanagh *et al*[16] in which the authors compared healthy age matched controls with participants suffering from DPN who had increased balance impairments than age matched healthy controls. They concluded the impaired sensory discrimination as the basis of increased postural instability in DPN[16].

Another study found that neuropathy in type 2 diabetes may enhance postural instability even in absence of dysfunction of the vestibular system[17]. This fact is of pertinent importance in geriatric population who are at increased risk of fall with increase in age in type 2 diabetes. Hence early detection of the problem is eminent in the prevention of fall related injuries in this population.

Table V. Correlation values of MNSI score with postural stability measures in four conditions

Surface: Firm; Condition: Eyes open		
Variable	Correlation	Significance
MNSI and X	0.17	0.21
MNSI and Y	-0.01	0.95
MNSI and VM	0.07	0.59
MNSI and AP	-0.11	0.41
MNSI and ML	0.05	0.71
Condition: Eyes closed		
MNSI and X	0.33	0.01
MNSI and Y	0.23	0.09
MNSI and VM	0.32	0.02
MNSI and AP	0.15	0.29
MNSI and ML	0.37	0.01
Surface: Foam; Condition: Eyes open		
MNSI and X	0.06	0.68
MNSI and Y	-0.07	0.60
MNSI and VM	0.02	0.88
MNSI and AP	-0.16	0.24
MNSI and ML	-0.08	0.58
Condition: Eyes closed		
MNSI and X	0.27	0.04
MNSI and Y	0.11	0.44
MNSI and VM	0.27	0.06
MNSI and AP	-0.06	0.69
MNSI and ML	-0.20	0.17

MNSI, Michigan Neuropathy Score Instrument; X, sway velocity along X axis, Y, sway amplitude along Y axis, VM, velocity moment; AP, anteroposterior displacement; ML, mediolateral displacement

In the present study when the foam was added to examine balance impairments in the participants a deterioration in postural stability measures were observed, a reason could be due to inability to modify postural strategies in response to changing surface and environmental demands which is usually impaired in DPN leading to higher risks of fall[18]. Turcot *et al*[19] analyzed postural instability using accelerometer and found that diabetic patients with neuropathy had a higher lumbar acceleration values implying greater postural instability as compared to healthy individuals and diabetic patients without neuropathy. Other researchers have reported that postural instability

as seen in DPN might be further enhanced due to poor glycaemic control (as assessed by glycosylated haemoglobin)[9]. Lord *et al*[20] evaluated individuals with diabetes on deformable surfaces (foam) measured the degree of postural stability using a simple sway meter attached at the level of waist. They reported that participants with diabetes had greater sway amplitude as compared to healthy controls. However, individuals with neuropathy were not evaluated to confirm this hypothesis.

Another group of researchers compared the degree of asymmetrical weight distribution of the limbs, AP, and ML displacements by evaluating three groups, *viz.* participants with DPN, participants with only diabetes, and healthy age matched controls. They concluded that participants with DPN had a far greater postural sway as compared to those with diabetes mellitus and healthy controls[10].

In contrast to other researches[9,10,16,18,20], we evaluated postural stability measures with center of mass (COM) sway velocity along X and Y axis, velocity moment, anteroposterior and mediolateral displacement in all the four conditions EO, EC, EOF and ECF. There was a linear increase in the mean values of sway velocity along X and Y axis, VM, ML and AP directions in participants with DPN. A gender based difference in postural stability variables was also found. However, this could be attributed to higher number of men (n=43) as compared to women (n=18) in the study.

A unique finding of the study was that MNSI showed a significant correlation with velocity moment. This finding implies that the severity of neuropathy on MNSI may be indicative of balance impairments, hence a detailed balance assessment may be necessary to assess their likelihood of fall during functional activities. It was observed that higher mean value of MNSI could also be suggestive of deteriorating trends in postural stability measures in DPN under various environmental demands. Findings also suggest that age and duration of diabetes can be a critical factor in defining velocity moment of individuals with DPN.

In our view, MNSI can be modified for balance assessment that might be useful in detecting changes in velocity moment of individuals with DPN. At present, clinicians require a reliable tool that can be objectively used to quantify balance impairments either for diagnostic or therapeutic purposes. This can be desirable in clinical practice to evaluate the success of interventions for balance related problems in individuals with DPN. Other researchers have also

evaluated functional balance using Berg balance scale and found that patients with diabetic neuropathy showed a remarkable functional imbalance, increasing the risk of fall among elderly during day to day activities[21].

A review by Visser *et al*[22] has revealed that efficacy of clinically used balance tests are usually vulnerable by their variable execution and subjective scoring system. Clinical examination of postural control provides only a subjective estimate of the potential risk of postural abnormalities and may well omit abnormal functioning of selective elements of postural stability. Though in the current clinical scenario history taking and physical examination are the ineffable measures for evaluating balance related problems in clinical practice, it has been commonly observed that asking about the presence of prior falls is unreliable because individuals often forget their falls[22]. Moreover, posturography is an expensive equipment and may not be easily available in rural set-ups. Hence development and validation of these concise clinical scales with posturography may be important to gauge the balance impairments in DPN in a clinical scenario.

On evaluation of ML and AP displacements and MNSI for postural stability measures, these measures were found to be affected on firm and foam surface and had a significant increase with duration of diabetes and MNSI scores. This finding can be of core importance as it can put a valuable insight into postural stability measures that gets affected early in participants with DPN leading to an increased lateral sway or balance impairments in ML direction in static stance.

It is known that ML displacements represent postural stability at the level of hip and AP displacement represents postural stability at the level of ankle[15]. It is hypothesized this shifts from ankle to hip strategy is related to neurological deficit as seen in DPN[23]. One reason for change in ankle to hip strategy is that participants with neuropathy due to diminished peripheral sensation mainly depend on hip strategy. Hence, they primarily recruit their hip abductors and adductors leading to increased ML displacement. This could also be an inclusive factor for higher mean values for mediolateral displacements from EO to ECF in our study.

There are studies reporting that using vision as a clue to enhance postural control in neuropathy seems to be ineffective during quiet static stance in DPN. The authors further reported that ankle motor activities were affected in DPN during quiet standing in ML direction[14].

Only a few researchers have analyzed data in ML axis[10,24-30]. In contrast with the other researches Kim and Robinson[28] found a significant difference in postural sway variables in diabetic neuropathy and healthy controls in AP and ML axis. Results in the present study suggest a multidirectional involvement of postural stability measures. We found an interaction effect of ML in firm and foam surface with duration of diabetes and MNSI implying ML instability with increase in duration of diabetes and MNSI scores. There was also a subsequent increase in mean value for AP strategy. Hence directing management to only one strategy is questionable in rehabilitation.

We found positive moderate correlation between MNSI and X axis, MNSI and VM and MNSI and ML on firm surface. Correlation of these variables indicated that one variable was paired or associated with relative positive value of another variable.

This study had a few limitations as there was no comparable group of healthy individuals hence the difference in postural impairment among DPN population and healthy counterparts was not known. We suggest that future studies should focus on dynamic postural impairments on foam or deformable surfaces under different environmental demands to replicate the magnitude of the problem in DPN during day to day activities or tasks.

In conclusion, evaluation of postural stability in Indian population with DPN indicates balance impairments on both firm and foam surfaces. Postural sway in DPN appears to be multidirectional, which surges the magnitude of balance impairment in static stance on the foam surface. This implies that there is a greater likelihood of fall among elderly adults with neuropathy when they come in contact with deformable surface during their activities of daily living. MNSI can be a useful tool for clinical examination in DPN in identifying individuals with higher risks of fall.

Conflicts of Interest: None.

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