



Review Article

Postural sway and weight distribution in diabetic neuropathy patients: narrative Review.

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Abstract

Background: Type 2 Diabetes mellitus is a common metabolic condition increasing in the elderly population which leads to various disabilities and in longtime can cause chronic complications like diabetic neuropathy, diabetic nephropathy, diabetic retinopathy and diabetic cardiopathy.

Objective: The aim of this narrative review is to identify the sway in posture and distribution of weight in bilateral stance in diabetic neuropathy patients.

Methods: The articles are taken from Google Scholar, PUBMED, and EMBASE MEDLINE.

Results: Increased anterior displacement than medial, lateral and posterior displacement in postural sway both in eye closed and eyes open, center of pressure and center of mass also changes in postural stability which will aid to identify risk of fall. In weight distribution there is an increased plantar pressure in anterior direction and higher plantar pressures were obtained in long standing phase.

Discussion and Conclusion: Early detection of postural sway in diabetic patients may decrease in risk of fall, identifying the muscle strengthening and balance impairment. Even early detection of improper weight distribution over the lower limbs mainly over the foot can reduced the presence of plantar pressure sores, risk of falls and balance instability, or diabetic foot. Postural sway and weight distribution is measured in stance phase than dynamic phase, increase in postural sway can cause to risk of fall and increase in weight distribution on limb can cause wear and tear of the structure.

Keyword: Postural Sway, Diabetic Neuropathy and Diabetic Nephropathy, weight distribution, plantar pressure, diabetes mellitus, diabetic foot.

Introduction

Diabetes is a metabolic disease which leads to hyperglycemia resulting from defects in insulin secretion and insulin action, or both. Increased blood

sugar level shows clinical features of frequent urination, increased thirst, and hunger.¹ Sedentary lifestyle is the important causative factor for the development of type 2 diabetes, including, obesity, lack of physical activity, poor diet and stress.²

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Diabetic Neuropathy

Diabetic neuropathy is the most common complication in diabetes mellitus which leads to the damage of the lower limbs like foot ulcer and postural instability. Diabetic neuropathy causes axonal degeneration in nerve fibers, demyelization of the nerve fibers results in Schwann cell dysfunction this leads to develop neuropathic syndromes such as somatic, peripheral and autonomic nervous system³ and also it can cause loss of sensory input and proprioception. Diabetic neuropathy acts as an independent variable for increased risk of falls.⁴

Postural Sway

Postural sway is a test to assess muscle activity during standing and induces a continuous to-and-fro movement of projection of the point of gravity.⁵ Whenever there is a disturbance in sensory input and/or the motor output, an abnormality of the postural sway is expected.⁶ Various tools like GRAVICHART, POSTUOGRAPH, postural sway meter with eye open and eye closed (Figure 1&2) were used to assess the postural sway of an individual. As the time progress neuropathic patients develops a certain gait characterized by hip strategy, lower gait speed, wider stance, reduced gait cycle amplitude, reduced ankle foot mobility and more carefulness to avoid falling with a more cognitively dependent gait control.⁷

A) Postural Sway Measurement



Figure 1: Lateral view of Measurement



Figure:2 Posterior view of Measurement

Weight Distribution

Individual's weight bear bilaterally, gradually they start to weight bear on either left or right lower limb (Figure 3&4), continuous weight bearing on one limb causes more of wear and tear of the lower limb. Progressive wear and tear of limb leads to permanent damage of the limb.⁸ The more differences of weight distribution between the dominant and non-dominant lower limb leads to wear and tear of ankle soft tissues, over pressure and finally ulcer. Improper weights distribution can lead to many complications.⁹ The narrative review intends to provide prevention of falls and fall-related injuries in diabetic neuropathy patients, commonly used methods and equipment for measuring postural sway and weight distribution.

B) Weight Distribution Measurement

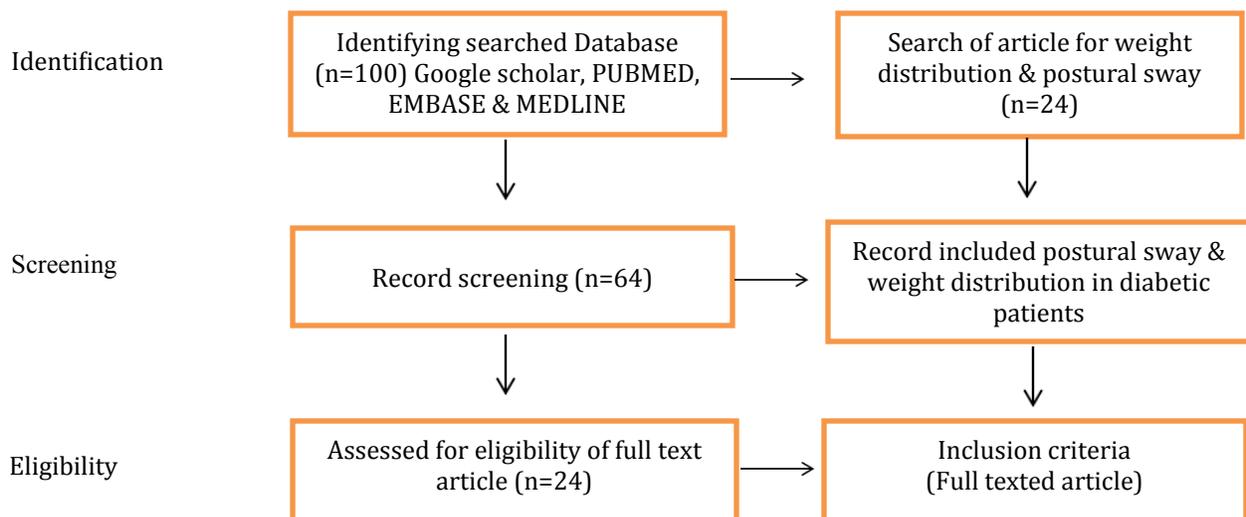


Figure: 3 Posterior view of Weight distribution



Figure: 4 Anterior view of weight distribution

Methods and Methodology



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Table 1: Demography of Diabetes Mellitus

Author	Methodology	Population	Age group	Remarks
Roglic G. Green A et al. 2012	Diabetes mellitus is higher in adults in USA, China, and Switzerland. 21st century claims 2.5% increase in the diabetes mellitus in middle east, Africa, and India. . In Asia the number of patients with diabetes mellitus will very high in 2030. Economically, advanced countries will increase about 50% in 2030, number of people estimate in India 31.7% in 2000 and in 2020 it will increase about 79.4%. ¹⁰	Type 2 diabetes mellitus	not mentioned	This study focuses on link between obesity, diabetes mellitus and abnormalities in immune system. Diabetes mellitus block the globalization of body mass increase in world population
Ahmed. AM et al. 2012	Population of 366 million people has diabetes mellitus 2011. The report has showed that 439 million people will be having type 2 diabetes mellitus by the year of 2030, report estimated 25.8 million people in US, India 40million. ¹¹	Diabetes mellitus	Not mentioned	Type 2 diabetes mellitus is a metabolic disease that can be prevented through lifestyle modification, diet control and obesity. Novel drugs are still beginning developed, yet no cure is available in sight for the disease
Joshi SR et al. 2014	Diabetes is fasting gaining the status of a potential epidemic in India with the disease. In 2000 India with 31.7 million people with diabetes mellitus, next china and United States 17.7 million. The prevalence of diabetes is predicted to double globally from 171 million in 2000 to 366 million in 2030. Maximum increases in India. By 2030 diabetes mellitus may affect up to 79.4 million individual in India while in China 42.3 million and United States 30.3 million. ¹²	Diabetes mellitus	Not mentioned	In India due to migration of people from village to cities areas, the economic boom, and corresponding change in life style are all affecting the level of diabetes Yet despite the increase in diabetes there remains a paucity of studies Investigation the Precise status of the disease because of the geographical, socio economic and ethnic nature of diverse country.
Zargar ah et al.	According to the international diabetes federation there was an estimated 387 million individual with diabetes worldwide in 2014 and this number is set to increase to 592 million by the 2035. Increased mortality related to diabetes in India is related to poor overall healthcare, with 59.11% dying within 1 week of hospitalization with infections and chronic renal failure being the major causes of death. ¹³	Diabetes mellitus	Not mentioned	It is important to realize the necessary cost effective measure of diabetes care, early screening, tight metabolic control, monitoring of risk factors, and assessment of organ damage. Understanding of both patient and physician barriers regarding proper monitoring and judicious use of therapeutic options, including insulin therapy, for optimizing diabetes management should be encouraged

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Saqf et al. 2015	In 2013 it has been estimated that 347 million people have diabetes mellitus worldwide. A literature search was performed from 2013-2014 in Australia, to retrieve information on evidenced based diabetic care. Diabetic knowledge questionnaire is a validated 24 item scale designed to assess the diabetic knowledge. Patients respond to the questionnaire by either answering yes or No, or don't know. ¹⁴	Diabetes mellitus	Not mentioned	This review of the literature has highlighted the importance of diabetes as a global health issue as well as discussed therapeutic goals, pharmacologic treatment, and effect of treatment on quality of life.
A Verrottiet al. 2009	Cardiorespiratory, Autonomic neuropathy were the adverse effect in which autonomic is the most clinically important and the well-studied form of diabetic autonomic neuropathy. ¹⁵	Diabetes mellitus	Not mentioned	The blood glucose onset of diabetes can delay nerve impairment and prevent the complication.
Emil Ginter et al. 2012	The main cause of Diabetes mellitus is obesity in Europe and USA. Obesity leads to insulin resistance can cause biomechanical factors such as abnormalities. ¹⁶	Type 2 diabetes mellitus	Not mentioned	Recent study shows the role of obesity and body fat in the metabolic disorder which links between obesity and type 2 diabetes mellitus.
Seema Abhijeetka veeshwar et al. 2014	Prevalence of diabetes is affected less in states like Chandigarh 0.12 million, Jharkhand 0.96 million compared to Maharashtra of 9.2 million And Tamil nadu 4.8 million. In cities 11.7 percent in eastern India, 61 percent in northern India, 16.6 In southern India. ¹⁷	Diabetic neuropathy	Not mentioned	Diabetes in rural populations is more than of urban population in India. Preliminary results from a large group of study Conduction was present.
Gordon Sloan et al. 2018	Imaging studies have confirmed that diabetic distal symmetrical polyneuropathy involves the peripheral and central nervous system, with reduction in spinal cord and primary somatosensory cortical grey matter volume. ¹⁸	Diabetic neuropathy	Not mentioned	Pain processing in higher order brain regions appears to be neuropathic pain in diabetic distal symmetrical polyneuropathy. Limitation: advanced MRI techniques has potential for the understanding the role of central nervous system in the generation, maintenance of pain, identify the new treatment targets. Research applied on several test subjects, founded that the percentage of a normal foot is between 80-88% than the percentage of foot with high arch, lower the percentage in the flat foot. So, the pressure values in both the foot can be measured to find the unbalancing between them.

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Table 2: Postural Sway Measurements.

Author	Measurements	Population	Age Group	Remarks
Helene Cor-riveau et al. 2000	Fifteen elderly with distal neuropathy and 15 healthy age matched subjects were evaluated with the biomechanical variable COP- COM, which represents the distance between the center of pressure and the center of mass. Measurements were taken in the quiet position with a double leg stance. In eye open and closed conditions. Subjects were also assessed with clinical balance evaluation. ¹⁸	15 diabetic neuropathy patients and 15 healthy individuals	Not mentioned	The COP-COM variable was statistically similar to larger in the DNP group than in the healthy group in anterior posterior and medial lateral directions. The DNP group showed statistically increased amplitudes of the COP COM variable without vision. The severity of the neuropathy while walking has scored between COP - COM amplitude in both the directions.
T. Brandt et al. 2001	The focus is to evaluate the postural and peripheral neuropathy by gravicorder and posturography ¹⁹ electrophysiological tests, and power spectrum analysis of heart rate fluctuations were assessed in subjects.	123 type 2 diabetes mellitus patients	Not mentioned	Diabetic patients with neuropathy have an increased prevalence of metatarsal fractures compared to diabetic patients without Neuropathy Diabetic patients with cutaneous sensory deficit in foot exhibited significantly poorer equilibrium comparison to Control subjects. These results indicate that significant balance loss cutaneous deficit of foot places the patient at increased risk for falling
Tinetti M et al. 2006	Parameter estimation by sequential testing was used with a two alternative forced choice paradigm. In this study, By stance was used because the center of pressure could be measured more reliably from that stance. For testing displacement perturbation, the subjects had headphones producing a constant masking with noise of 70db and blind-fold. Subjects were asked to press a wireless doorbell chime held in their hand once or twice if they detected a movement at one or two respectively, right after the decide instruction. ²⁰	Diabetic neuropathy patients	Not mentioned	The postural Steadiness and detection of perturbation results to designing floor mats or safety boot insoles to prevent fatigue of the lower extremities or slips in workplaces

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Mendez- Villaneuva A et al. 2008	<p>Postural control was assessed in an upright bipedal stance in 60 male volunteers by different Closed- stance positions. Six different tasks were given to perform with two trials including a cognitive task, eyes open, head in a neutral position (EO); eyes closed, head in a neutral position (EC); eyes closed, head back (ECHB); eyes open, head in a neutral position. Dependent variables were area of 95th centile ellipse (AoE) and sway path length(SPL).²¹</p>	60 male volunteers	Not mentioned	<p>Participants showed increases in SPL and AoE in EC and ECHB trials. Increased SPL but not AoE. Controls showed a slight, non-significant change in postural control (reduced SPL and AoE) when Attending to concurrent mental tasks.</p>
Horak FB et al. 2011	<p>Postural sway in quiet standing is often studied as a measure of postural control. Many instruments to measure sway in high end plates are used to measure postural sway. Postural sway in standing was analyzed sway meter.²²</p>	60 College Students	18- 24 YEARS	<p>This study shows sway was increase anterior (5cm) than medial, lateral and posterior sway.</p>
Miata v. VAZ et al. 2013	<p>Upright balance, evaluated in 4 situations (fixed platform, unstable platform, eyes open and eyes closed) and functional strength, assessed with a five times sit to stand test, were analyzed using an electromagnetic system, with a sensor placed over C7 to allow maximum trunk displacements in the anterior, posterior and medial, Lateral displacement. The berg balance scale and timed up and go test were used.²³</p>	Type 2 diabetes mellitus patients	Not mentioned	<p>Subjects with DM2 had greater anterior posterior displacement in the unstable platform with eyes closed condition compared with those without DM 2, whereas no difference in medial lateral displacement was observed between Groups. A difference in time was observed in the five times sit to stand test with subjects performing the task faster than either group of subjects with DM 2. Additionally, subjects in the controlled group showed a higher score in the BERG BALANCE SCALE and performed the timed up and go test in less time compared with subjects in other groups</p>

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Aranda R et al. 2014	The study included 50 subjects of DM, Stepwise multiple linear regression was used to assess diabetes mellitus –which were related to factors that affected postural sway. ²⁴	50 subjects with diabetes mellitus	50 - 57 years	Subjects with diabetes mellitus and vestibular impairments showed a deterioration of postural sway.
Guariguata L et al. 2015	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) were used to analyse the changes in postural stability measures in different conditions. ²⁵	61 patients with diabetes mellitus	Not mentioned	An increase in mean value of postural stability measures was observed for velocity moment mediolateral displacement and anteroposterior displacement from eye open, to eye closed, Eye open in firm and foam surface and eye closed in firm and foam, respectively. With greater sway amplitude on firm and foam surface in all the conditions. Moderate correlation of MNSI with age and postural stability measures were also observed.
Whiting DR et al. 2020	Total 145 individuals were screened for MNIS and the individual who fulfilled the inclusion and exclusion criteria was included in the study according to the sample size, 60 patients were selected postural sway was assessed by modified clinical test of sensory interaction on balance test of posturography by balance master and dynamic balance was assessed by dynamic gait index. Data was recorded and then analyzed with Spearman's correlation coefficient test. ²⁶	Diabetic mellitus patients	Not mentioned	The correlation between sway in 4 different situations (opened and closed of eye on firm surface and foam surface) and dynamic balance was correlated. There was no statistical difference found between static and dynamic balance. To maintain the relation of the center of mass and base of support the postural sway occurred.

Table 3: Weight Distribution Measurement.

Author	Measurements	Population	Age Group	Remarks
Z Pataky, J Pasa- sal et al 2004	Increased plantar pressure in anterior displacement of weight bearing in diabetic patients without evidence of any micro and macro vascular complications such as early peripheral neuropathy not detected on clinical evaluation and plantar Soft tissue thickness well as plantar fascia abnormalities. Limitation: sample size, additional studies on both plantar soft tissue and plantar fascia structures in early diabetes. ²⁷	Type 2 diabetes mellitus subjects without peripheral vascular disease	More than 45 years old	There was an increased plantar pressure as well as the anterior displacement of weight bearing. Peripheral neuropathy not detected on clinical evaluation and plantar soft tissue thickness well as plantar fascia abnormalities. Limitation: sample size, additional studies on both plantar soft tissue and plantar fascia structures in Early diabetes.
Robert van Deursen et al 2004	There were different aspects of mechanical loading of the foot and the ways of reducing mechanical load in biomechanical terms. The biomechanics of the foot during basic activities of daily living and the magnitude of the mechanical load of the foot and the changes in the diabetic foot can lead to increase of mechanical loading compare to the normal foot. ²⁸	Diabetic foot subjects	Not mentioned	The different mechanisms were used to achieve the desired effect of offloading ulcerative area. There was an understanding of the underlying biomechanical principles can be achieved by plantar offloading. The result can be in an optimization of available offloading devices.
Susan Hopkins et al. 2013	Participants were measured standing astride two scales. Short term volunteers were measured 10 times on one visit, with repositioning between measurements and the long term group were Measured on three visit at 6 month intervals. Baseline bilateral hip and total body dual x-ray were performed in long term group. ²⁹	Volunteers from mixed group	19 to 54 years old	Weighing with the supports resting on the adjacent floor in their normal standing, supported position. Relative left and right weight bearing is then calculated as a percentage of their total unsupported weight. Limitation: dual scales technique is that it measures weight bearing in an upright stance and this may not be representative of typical weight bearing during other activities including Walking.

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Fragoon et al. 2013	In order to design an electronic foot screening protocol, it was used by the optical method. After that it was divided into 2 phases: phase one consist of optical unit, processing unit, display unit and phase2 of vibro- tactile circuit. So, the total body weight of the person is taken with standing straight on the foot and results are displayed in personalized computer. ³⁰	Diabetic population	Not mentioned	Research was applied on several test subjects, founded that the percentage of a normal foot is between 80-88% than the percentage of foot with high arch, lower the percentage in the flat foot. So, the pressure values in both the foot can be measured to find the unbalancing Between them.
Paulo Henrique Ferreira de Araujo – Barbosa et al. 2014	Alternative way of assessing weight bearing asymmetries, the measures obtained from the digital scales has been used as the index to classify weight bearing distribution. It describes the intra test and the test /retest reliability of measures in subjects with or without hemiparesis during quiet stance ³¹	Subjects with or without hemiparesis	29 to 81 years old	It was supporting the use of digital scales. The behavior Of the measurements analyzed by repetition intra- test could reveal important features of the weight bearing distribution calculated from digit scales. So, the measurement obtained from digit scales was reliable for the subjects with or without Hemiparesis.
Malindue. fernando et al 2016	Cases with Type 2 Diabetes Mellitus and Diabetic foot ulcers, Type 2 diabetes controls and healthy controls were recruited for the study. Exclusion criteria for all groups included: orthopaedic, musculoskeletal, vestibular, visual or neurological problems. Plantar pressures at 10 sites on both feet and stance phase duration were measured. Primary outcomes were mean peak plantar pressure, pressure time integral and stance phase duration. ³²	Type 2 diabetes	Above 66 years old	The plantar pressures were higher in cases with active unilateral diabetic foot ulcers compared to diabetes and healthy controls without ulcers. The higher plantar pressures occurred in cases when compared to long stance phase duration. The importance of offloading foot during active ulceration has to overcome the mechanical impact of elevated plantar pressures on ulcerated tissues. Inability to adjust analysis for multiple factors
Edyta Sutkowska et al 2019	Distribution of the region of the highest plantar pressure defined as a static, peak plantar pressure, which were assessed by the prevalence of abnormal pressure distribution. The results were obtained as colorful print Analysis among association between this pressure and selected factors: neuropathy, age, gender, BMI. The plantar pressures were assessed by using a semi-quantitative method. The intensity of color was proportional to the pressure received. Warm colours indicated the greatest pressure, while cold colours indicated the least plantar pressures ³⁵	Type 2 diabetes mellitus	BMI < 35	The baseline of study population appear to be typically for subjects with Type 2 diabetes, and the results could change for different types of Diabetes mellitus. The disease duration may be connected with higher peak pressure within the feet due to plantar contact near narrowing. Age and duration of diabetes are connected with ulcers and amputations, so it cannot be ruled out that both could also influence the pressure distribution. Limitation: semi-quantitative analysis of the pressure map, the retrospective nature of the study.

Discussion

Diabetic neuropathy is a major cause of neuropathy worldwide and may lead to amputation and incapacity (Table 1). Early and accurate diagnosis allows or adequate treatment, preventing progression of neuropathy and severe complication. Diabetic foot complications are the simple and more common complications seen in diabetic foot.²⁴ Studies confirm the importance of risk factor of diabetic foot in addition to demonstrating the importance of diabetic retinopathy as a significant risk factor during screening.²⁴ All the study showed limitation such as; hospital based retrospective nature which lacks certain specific information and being cross section study which is not the right set up for determining causality.²⁵

Various facilitators such as automobiles, television and computers, brought convenience and comfort of formidable opponents of the struggle to return to healthy life style.²⁵ There is definite decrease in Physical activities which had detrimental effects on body mass index and insulin level. Healthcare providers should engage patients in self-management education to facilitate behavior change such as health education towards diabetes, Knowledge regarding the disease is still key for the epidemic²⁵, Result oriented organized programs involving patient education, updating medical fraternity on various developments in the management of diabetes, and providing the management and providing then the opportunity to use and analyses these newer treatment options in the form of observational studies are required to combat the diabetes epidemic currently threatening to affect the lives of millions people in India.²⁶

Diabetes mellitus in rural populations is more than of urban population for India, which is very evident in all the preliminary survey across the metropolitan cities of India.²⁶ The threat that type 2 diabetes mellitus is epidemically represents to the mankind, with the recent discoveries in the metabolic disorder i.e.; Links between obesity and diabetes mellitus describes abnormalities in immune and cytokine responses of metabolism in the fat cell.²⁷

Postural Sway Measurement

Postural sway is most common in anterior and posterior side, rather than right side or left side where the anterior sway and posterior sway is about 15° and 10° respectively (Table 2).²⁷ The greater the displacement, risk of fall in elderly population especially the individuals with peripheral neuropathy showed high risk. In western countries, multiple studies showed postural instability amongst elderly

diabetic population where the COP – COM variable used as a diagnostic tool to detect change in the postural stability and it also identifies DNP at risk falling.²⁶ Diabetic patients tend to sway more on an elastic pad than on a hard floor when compared with people with no diabetes.²⁷ Modifications of floor mats or shoe insoles, based upon the relationship between sway directions and perturbation detection, can reduce the intensity of change of center of pressure, resulting in more stable balance for diabetic patients.²⁸ The GRAVICHART is used as one of the screening tools in various studies for diagnosing postural balance impairment.²⁸ With regard to the various variables in multiple studies, no difference was observed between individuals with DM2 and without distal neuropathy. All the study indicated that, it is not necessary that an increase in postural sway indicates poor balance.²⁹ In addition, the sway meter paves a better tool to identify postural sway in all the clinical trial. In another study, standard postural sway indices were not able to elucidate whether expertise in surfing to the facilitated adaptations for the postural control system.⁵ Concurrent mental task findings illustrate those systematic differences in balance abilities between expert surfers and vestibular impairments showed a deterioration of postural sway.³⁰ Evaluation of postural stability in Indian diabetic neuropathy 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 and showed inability to maintain an upright posture.³⁰

Weight Distribution Measurement

Abnormal weight distribution in the bipedal stance laid foundation to various assessment tools; the frontier of all of them is electronic foot screening protocol used by the optical method.³¹ The total body weighing is simple method, standing straight on the foot displays consistent weighing difference in bipedal stance.³¹ An alternative way of assessing weight bearing asymmetries is bilateral digital scales usage where the index of classifying weight bearing distribution is identified.³² In their normal standing or supported position relative left and right weight bearing showed variations both in supported and unsupported weighing system.³³ Studies shows that there is increased plantar pressure in the anterior displacement of weight bearing of type 2 diabetic patients without evidence of any micro and macro vascular complications.³³ In another study, distribution of highest plantar pressure in right foot showed static peak plantar pressure, which were correlated with the complication of the diabetic complications (Table 3).³⁵

Limitations of the study

This study aims to find out the postural sway and weight distribution in type 2 diabetes mellitus only whereas type 1 is not addressed. Moreover, this literature compress of last 5 years (2015- 2020) data and the quality/level of evidence is not addressed.

Future Recommendations

Large strate of study population and non-English research articles can be included in the future narrative review.

Conclusion

In this review it has shown that the demography of type 2 diabetes mellitus has nearly 72% of the global population. The complication of diabetes mellitus mainly includes retinopathy, nephropathy, cardiopathy and neuropathy, where the most common complication is peripheral neuropathy. Postural sway in diabetes mellitus causes greater displacement in anterior direction rather than medial, posterior and lateral direction. Medial lateral displacements represent postural stability at the level of hip and anterior posterior displacement represents postural stability at the level of ankle. The greatest decrease in postural stability has been observed with eyes closed and this finding reveals a relevant on vision to compensate for sensory deficits. Weight distribution of the diabetes is measured in stance phase than dynamic phase and mainly effects on the weight bear on the non-affected side of the limb. Highest plantar pressure sores were obtained in long standing phase than dynamic phase.

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