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Substantial Aspects of Balance in Patients with Diabetic Neuropathy: A Physical Therapist's Perspective

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INTRODUCTION

DIABETIC NEUROPATHY

Diabetic neuropathy is defined as the presence of symptoms and or signs of peripheral nerve dysfunction in people with diabetes after the exclusion of other causes. The neuropathic disorder includes manifestations in the somatic and or autonomic parts of the peripheral nervous system.[1]

Neuropathy, a common complication of diabetes mellitus, is generally considered to be related to duration and severity of hyperglycemia. However, it may also occur acutely even with hypoglycaemia. Usually more than 50% of patients with duration of diabetes of 25 years or more are affected, making it as one of the most common disease of the nervous system.[2]

It is estimated that at least 50% of diabetic patients will develop neuropathy in their lifetime. Neuropathy is the most common "life-spoiling" complication of diabetes mellitus and may lead to painful foot ulceration, Charcot neuroarthropathy, and symptomatic autonomic dysfunction. Diabetic neuropathies are a heterogeneous group of disorders with different mechanisms. They can be proximal or distal, focal or diffuse, affecting both peripheral and autonomic nervous systems, causing pathological changes with great impact on the quality of life of the patients, resulting in early mortality.[3]

Diabetic neuropathies also appear to be more common in people who have problems controlling their blood glucose, also called blood sugar, as well as those with high levels of blood fat and blood pressure and those who are overweight.[4]

Diabetic neuropathy affects the longest nerves which send messages about touch, pain and temperature sensations to the brain from the feet and lower legs. In some people it can affect the hands as well.[5] It may interfere with general activity, mood, mobility, work, social relations, sleep, leisure activities, and enjoyment of life.[6]

People with peripheral neuropathy caused by diabetes often experience balance disorder. Postural sway in these patients is increased.[7]

Causes of diabetic neuropathy includes Diabetes, Autoimmune disorders ,Chronic kidney disease, Human immunodeficiency virus and liver infections, Low levels of vitamin B12, Poor circulation in lower extremities, Underactive thyroid gland, Trauma, Tumor.[8]

Risk factors of diabetic neuropathy includes Advanced age' Alcohol intake' Dyslipidemia' Genetic factors, Hypertension, Increased height, Poor glycemic control, Tobacco abuse, Vitamin B12 deficiency, Rheumatoid arthritis[9]

Pathology of diabetic neuropathy[10]

Auche and Fraser and Bruce described degeneration of the peripheral nerves, and Pryce, Leichtentritt and Williamson" described demyelination and gliosis of the dorsal columns of the spinal cord in diabetics.

The lesions of neuromusculoskeletal systems:

Brain- There is no specific encephalopathy. Diabetics are often hypertensive and tend to have severe atheroma. They are therefore more prone to suffer cerebral infarcts and haemorrhages, and to do so at an earlier age than the average

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person. These lesions do not differ in any respect from those incurred by non-diabetic subjects and therefore need not be discussed further.

Cranial nerves-The majority of the cranial nerves have shown dysfunction clinically. Unfortunately, pathological observations are almost non-existent.

Spinal cord - The spinal cord, like the brain, may be the seat of infarcts due to vascular insufficiency. The spinal cord may also undergo a variety of more specific degenerations, of which the most frequently encountered involves the dorsal columns; the upper segments of the cord are selectively affected. The dorsal roots not only participate in this process but are often more severely demyelinated. Axis cylinders again are less affected. Occasionally, fibrosis has been noted, but it is usually not prominent. The severely demyelinated dorsal roots may provide a striking contrast to the normal anterior roots even though the dorsal horns are normal.

In the dorsal root ganglia, various degenerative changes varying from peripheral vacuolization to complete dissolution of neurons has been reported, with resultant loss of axons and proliferation of the capsule cells. These lesions are minor and they are greatly overshadowed by the root lesions.

Peripheral nerves- The most frequently noted and severest damage is found in the peripheral nerves. The lesions are usually fairly symmetrical and often most extensive in the distal portions particularly affects the sciatic nerves and its branches.

Greenbaum et al. felt that large fibres suffered most and that axons degenerated to the same degree as myelin sheaths, and concluded that the process was essentially a primary neuronal degeneration.

Thomas and Lascelles" confirmed this claim by finding segmental demyelination and remyelination in teased out isolated fibres of diabetic sural and radial nerves. In a few fibres, axonal degeneration had occurred.

There is degeneration of peripheral nerves with segmental demyelination, some loss of axons (both A and C fibres) and degeneration of terminal motor axons and end plates.

Autonomic system - is clinically most severely affected in diabetes. Appenzeller and Richardson recently described giant neurons about twice the normal size, exhibiting severe degenerative changes and even dissolution in the sympathetic ganglia.

Muscles – small foci of typical neurogenic atrophy was seen in the muscles of the foot and leg of diabetics.

Clinically weakness and atrophy have often been most pronounced in proximal muscles particularly in the thighs and in the pelvic and shoulder girdle.

Joints –Charcot's joints particularly affecting the tarsal and proximal metatarsal joints, but occasionally the ankle, knee and spine is a complication of diabetes.

Clinical features of diabetic neuropathy [11]

Symptoms most commonly seen are tingling sensation, burning pain, electrical or stabbing sensations, Hypersensitivity, deep aching pain, weakness, imbalance, and fatigue falls

Signs

- Distal sensory loss
  - -Vibration
  - -Pin prick
  - -Temperature
- Absent or reduced ankle reflexes
- Distal weakness
  - -Toes
  - -Fingers

BALANCE:

DEFINITION OF BALANCE

Balance is the ability to control the centre of gravity over the base of support in a given sensory environment.[12]

Posture control involves controlling the body's position in space for the dual purpose of stability and orientation.[13]Postural control is the ability to maintain equilibrium and orientation in a gravitational environment.[14]

COMPONENTS OF BALANCE[15]

Sensory modalities
Three sensory modalities are mainly involved in postural control: somatosensory, visual, and vestibular afferents. Integration of information from these systems is crucial for adequate postural control.

Sensory information is regulated dynamically and modified by changes in environmental conditions. Despite the availability of multiple sources of sensory information, in a given situation, the central nervous system (CNS) gives priority to one system over another to control balance in the orthostatic position.

Biomechanical Constraints
Postural stability can be understood as the ability to keep the centre of gravity (CG) within the limits of the BS, or stability limits; these limits are not fixed, but rather can be modified according to tasks, movements, individual biomechanics, and environmental aspects.

Thus impairments in range of movement, tone, strength, and muscle control can influence postural control. The CNS has an internal representation of stability limits and uses it to determine how to move and maintain balance

Movement Strategies

The human body has postural strategies that are general sensorimotor solutions for postural control and include ankle, hip, and step strategies. These strategies involve muscle synergies, movement patterns, joint torques, and contact forces.

Cognitive Processing

Motor responses and activation of muscle synergies are influenced by sensory feedback and also by expectation, attention, experience, environmental context, and intention.

Perception of Verticality

Adequate orientation in space is critical for postural control. Perception of visual verticality is independent of postural verticality. Postural perception of verticality has multiple neural representations.

Motor processes which include organizing muscles throughout the body in the neuromuscular synergy. Sensory or perceptual process involving the organization and integration of visual vestibular and somatosensory, higher level process essential for mapping sensation to anticipatory and adaptive aspects of posture control.

NEUROPHYSIOLOGY OF BALANCE[15]

Peripheral input from visual, somato-sensory, and vestibular systems are available to detect the body position and movement in space with respect to gravity and environment. Each frame provides a different reference for posture control.

The vestibular system provides input concerning the position of the head in relation to gravity as well as to motion through the liner and angular acceleration of the head. Information concerning movement of body segments with reference to each other is provided through the somatosensory system, proprioceptive, Cutaneous, and joint input. The visual systems provide information about the body's position relative to the environment. Brainstem nuclei are active in the regulation of postural tone, integration of sensory information for posture and balance.

The cerebellum is known to control adaptation of postural responses that is, the ability to modify postural muscles response amplitudes in response to changing environment and task condition. The basal ganglion are involved in the control of postural set that is, the ability to quickly change muscles pattern in response to changing task and environment condition.

BIOMECHANICAL ASPECTS OF BALANCE[16]

Postural component of balance control

There are two elements to the need for postural control imposed by the Earth's gravitational pull. First, even a stationary body must do work to remain upright under the force of gravity, particularly the tall human frame with its small BOS, Second, postural control is necessary to counterbalance any movement which alters the projection of the COM of the body to the ground.

Equilibrium component of balance control

Equilibrium control relates to maintaining inter-segmental stability of the body and its parts despite the forces acting on it.

Task influences on the biomechanical parameters of balance control

The activity undertaken determines the magnitude, direction and combination of the forces of gravity and acceleration, changing its biomechanical parameters throughout the task.

Environmental context influences the biomechanical parameters of balance

The environmental context of a task can alter its biomechanical parameters in two ways. The first and more major essential utilises two types of learned proactive mechanisms to reduce or counteract stresses acting on the body. The second essential consists of largely automatic reactive mechanisms that respond to failures of proactive components or to unexpected external perturbation.

Environmental influences on information processing for balance control

The amount of information processing required depends on the complexity of the environment and whether it changes throughout the activity.

Task influences on information processing for balance control

The central processing area handles complex information not only from the environmental context but also from the task itself. Like environments, complicated tasks require more information processing than simple ones. As with closed environments, closed tasks whose characteristics do not change from one trial to another require less information processing with practice.

EFFECT OF DIABETIC NEUROPATHY ON BALANCE

Patients with polyneuropathy, which reduces sensation and often strength in the lower extremities, have decreased stability while standing and when subjected to dynamic balance conditions. In patients with severe peripheral neuropathy of unknown origin, compared to healthy age and sex matched controls, visual and vestibular input cannot

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fully compensate for the impairment in proprioception, with progressive deterioration of balance.

The ability to re-weight sensory information depending on the sensory context is important for maintaining stability, when an individual moves from one sensory context to another, such as a flat walking surface to an uneven surface or a well-lit sidewalk to a dimly lit garden. Individuals with peripheral vestibular loss or somatosensory loss from neuropathy are limited in their ability to re-weight postural sensory dependence.

In patients with peripheral neuropathy, including Charcot-Marie-Tooth disease type 1A and type 2 and diabetic neuropathy, the effects of impaired proprioceptive input in balance control under static and dynamic conditions showed that, during static conditions, across all patients, instability increased as a function of the slowing of conduction velocity.

In contrast, during dynamic conditions head displacement was only slightly increased, compared to healthy subjects, despite the increased delay at which the head followed displacement of the feet. Charcot–Marie–Tooth disease is a genetically heterogeneous group of hereditary neuropathies characterized by slowly progressive weakness and atrophy, primarily in the distal leg muscles.

The clinical disability has been shown to best correlate with the degree of axonal loss. Evidence suggest that functional integrity of the largest afferent fibres is not necessary for appropriate equilibrium control during quiet stance, and unsteadiness is related to additional functional alterations in smaller fibres, most likely group II spindle afferent fibres .

In adult patients with Charcot–Marie-Tooth type 1A, the decline in axonal function and in muscle strength may reflect, to a considerable extent, a process of normal ageing, and physical disability in adulthood may well be explained by decreased reserves and compensatory mechanisms together with progression of skeletal deformations due to muscle weakness.

During static conditions, patients with Charcot-Marie- Tooth type 2 may show less postural stability than patients with Charcot-Marie-Tooth type 1A disease, but similar than the postural stability shown by diabetic patients with peripheral neuropathy; while in patients with diabetic peripheral neuropathy, unsteadiness relates to alterations in medium-size myelinated afferent fibres, possibly originating from spindle secondary terminations.

A frequent source of polyneuropathy is diabetes mellitus. Diabetic peripheral neuropathy is initially characterized by a reduction in somesthesic sensitivity due to the sensitive nerve damage, and with progression motor nerves are damaged. During upright stance, compared to healthy subjects, recordings of the centre of pressure in patients with diabetic neuropathty have shown larger sway, as well as increased oscillation at 0.5-1 Hz. However, in this group of patients, in addition to postural instability caused by neuropathy, balance deterioration may also result from the bio-mechanical impairment caused by progression of foot complications, as well as from the compromise of other sensory inputs such as vision.

Compared to healthy subjects, diabetic patients may have poorer balance during standing in diminished light compared to full light and no light conditions. Balance and gait difficulties are the most frequently cited cause of falling in all age and gender groups.

A fall is often defined as inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, wall or other objects. Cavanagh et al. have shown that, compared to patients with diabetes but no peripheral neuropathy, patients with diabetic peripheral neuropathy are more likely to report an injury during walking or standing, which may be more frequent when walking on irregular surfaces.

Epidemiological surveys have established that a reduction of leg proprioception is a risk factor for falls in the elderly. Symptoms and signs of peripheral neuropathy are frequently found during physical examination of older subjects. These clinical manifestations may be related to diabetes mellitus, alcoholism, nutritional deficiencies, autoimmune diseases, among other causes. In this group of patients, loss of plantar sensation may be an important contributor to the dynamic balance deficits and increased risk of falls. Falls occur as a result of complex interactions among demographic, physical and behavioural factors.

Risk factors may be intrinsic or extrinsic: intrinsic factors include demographic and biological factors, while extrinsic factors encompass environmental and behavioural factors. Among other risk factors, the occurrence of falls may be significantly associated with lower extremity weakness, which can be measured by knee extension, ankle dorsiflexion, and chair stands, visual acuity of less than 6/12, lower extremity impairments and poly-pharmacy. Apart from sensorimotor compromise, fear of falling may relate to restriction and avoidance of activities, which results in loss of strength especially in the lower extremities, and may also be predictive for future falls.[17]

EVALUATION OF BALANCE

Static balance: The ability to maintain postural stability and orientation with the centre of mass (COM) over the base of support (BOS) and the body at rest .[18]

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Dynamic balance: The ability to maintain postural stability and orientation with the centre of mass over the base of support while parts of the body are in motion.[18]

TYPES OF BALANCE TESTS[18]

- **Quiet standing:**
  - Romberg
  - Sharpened Romberg
  - One legged stance test
  - Postural sway
  - Nudge
  - Postural stress test
  - Motor control test
- **Active standing:**
  - Function reach
  - Limit of stability
- **Functional scales:**
  - Berg balance scale
  - Get up and go/timed get up and go
  - Tinetti performance oriented assessment of balance
  - Tinetti performance oriented assessment of gait
  - Dynamic gait index

REVIEW OF LITERATURE

1. Alfonso-Rosa RM (2013), conducted a study to assess the intraclass correlation coefficients and to determine the minimal detectable change scores of the data for the Hand Grip Strength Test, the Chair Sit and Reach Test (CSRT), the Timed "Up and Go" (TUG) test, the 6-Minute Walk Test (6MWT) and 30 seconds Sit to Stand Test (30s-STS) test in older adults with type 2 NIDDM. It concluded that all tests are reliable outcome measures for type 2 NIDDM patients. This study has generated novel minimal detectable change data, which will assist nursing practitioners in both prescribing the most beneficial exercise and interpreting post treatment changes after rehabilitation in patients with Type 2DM.[25]

2. Chang SJ (2013), conducted a study to evaluate the psychometric properties (reliability and validity) of the Korean version of the Diabetes Self-efficacy Scale among South Korean older adults with type 2 diabetes mellitus. A total of 278 Korean older adults with type 2 diabetes were recruited in one senior centre in Seoul, South Korea. The instrument included the Diabetes Self-efficacy Scale and the summary of the Diabetes Self-care Activities. The findings supported that the Korean version of the Diabetes Self-efficacy Scale was reliable and valid in measuring self-efficacy as related to diabetes self-management in Korean older adults with type 2 diabetes.[26]

3. Marco Godi (2013), conducted a study to compare the psychometric performance of the Mini-BESTest and the Berg Balance Scale (BBS). Ninety-three participants with balance deficits were recruited.The result proved that the 2 scales behave similarly, but the Mini-BESTest appears to have a lower ceiling effect, slightly higher reliability levels, and greater accuracy in classifying individual patients who show significant improvement in balance function.[27]

4. Tabassom Ghanavati (2011), conducted a study to evaluate the functional balance in patients with diabetic neuropathy and normal older adults. The present case–control study was designed to test the ability of two fourteen DPN patients and healthy people to control functional balance using Berg Balance Scale (BBS).The correlation between DNE and BBS scores were calculated using the Spearman's correlation coefficient. There was a significant strong negative correlation between DNE and BBS scores. Thus DPN results in a remarkable functional imbalance that may expose these patients to danger of falling during daily activities and becomes more severe as the severity of neuropathy aggravates.[28]

5. Renata Ceredo, Jose Roberto Jardim et al (2009), conducted a study to find the various factors associated with functional balance and mobility among elderly diabetic outpatients. For this in study they recruited ninety-one elderly (65+ years) outpatients were assessed. Mobility was evaluated by the Timed Up and Go Test (TUGT) and the balance, by the Berg Balance Scale (BS). The results showed that there was a significant and independent positive relationship between TUGT and age, daily activities (ADL/IADL), step strategy, and proprioceptive sensitivity.[29]

6. Fay B Horak (2009), conducted a study to evaluate the Balance Evaluation Systems Test (BESTest) and to differentiate balance deficits. 22 subjects with and without balance disorders, ranging in age from 50 to 88 years, were rated concurrently on the BESTest .Concurrent validity was measured by correlation between the BESTest and balance confidence, as assessed with the Activities-specific Balance Confidence (ABC) Scale. They concluded that The BESTest is easy to administer, with excellent reliability and very good validity.[30]

7. Trina Smith (2005), conducted a study on Berg Balance Scale to quantify the balance of patients with diabetic neuropathy. Twenty one female and five males were selected. Participants completed each balance test once during 2 testing sessions for that inter rates reliability was good for the BBS. The balance test showed moderate to good reliability for this population.[31]

8. Stephen D. Jernigan (2002), conducted a study to identify the best tool to discriminate among four functional mobility fall risk assessment tools in people with diabetic peripheral neuropathy, between recurrent "fallers" and those who are not recurrent fallers. The participants were a sample of 36 individuals between 40 and 65 years of age with

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diabetic peripheral neuropathy. Fall risk was assessed using the Functional Reach Test,the Timed "Up & Go" Test, the Berg Balance Scale, and the Dynamic Gait Index. The result showed Ten of the 36 participants were classified as recurrent fallers.Overall diagnostic accuracy improved for all tests except the Functional Reach Test; the Timed "Up & Go" Test demonstrated the highest diagnostic accuracy at 88.9%.[32]

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