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Effects of Computer Based Interactive Balance Training on Functional Status in Individual with Diabetic Neuropathy

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ABSTRACT

Background: Diabetes mellitus (DM) is one of the largest global public health emergencies of the 21st century. Approximately 415 million adults have DM and by 2040 this number will rise to 642 million. Neuropathies are one of the most common complications of DM with a prevalence of approximately 60%. DN may cause balance problems when going about daily tasks. Falling is five times more common in patients with DN, and the consequences can be severe, including decreased mobility, avoiding activities, institutionalization, and death. These findings have been linked to altered functional gait and mobility as well as impaired postural stability and diminished balance. The aim of this study is to find out the effect of computer based interactive balance training on functional status in individual with diabetic neuropathy.
Methodology: 10 participants between the age group 30–60 years with Diabetic Neuropathy were selected with convenient sampling. Participants were given Computer based interactive balance training for 2 weeks duration. Balance were assessed before and after 2 weeks of intervention protocol by functional reach test and Timed up and go test.
Results: Result of this study showed that there were significant differences in post values of functional reach test (p=0.001), Timed up and go test (p=0.040) respectively after a 2 weeks of computer based balance training program. Significant improvement in balance and functional Status was seen.
Conclusion: This study concluded that 2 weeks of Computer based interactive balance training program improves balance and functional status in patients with Diabetic Neuropathy.

Keywords: Computer based interactive, balance, Functional reach, timed up and go, functional status, Diabetic neuropathy.

INTRODUCTION

Diabetes mellitus (DM) is one of the largest global public health emergencies of the 21st century. Approximately 415 million adults have DM and by 2040 this number will rise to 642 million. Neuropathies are one of the most common complications of DM with a prevalence of approximately 60%. Patients with type 2 DM (T2DM) may present with this complication after only a few years of known poor glycemic control; sometimes, these patients already have neuropathy at the time of diagnosis. The quality of diabetes self-management and patients' quality of life are significantly reduced by diabetic neuropathy (DN), which also worsens the prognosis of other diabetes problems. Many patients burn themselves while going about their daily activities because they are temperature sensitive. Unintentional but severe injuries that can become infected and require amputation might result from a lack of sensitivity, or loss of nociception, which can also cause foot ulceration.

DN may cause balance problems when going about daily tasks. Falling is five times more common in patients with DN, and the consequences can be severe, including decreased mobility, avoiding activities, institutionalization, and death. When descending stairs, individuals with DN experience the most balance impairment, which is primarily in the medial-lateral plane. When treating diabetic patients with altered gait, it is important to take into consideration both cognitive-behavioral aspects (fear of falls) and physiological factors (strength and proprioception).**[1]**

It has been widely accepted that DPN causes people with diabetes to perform less functionally. Reduced proprioceptive sensibility, decreased ankle range of motion, and decreased muscle strength particularly in the plantar and dorsiflexor muscles of the foot and ankle have all been linked to DPN. These findings have been linked to altered functional gait and mobility as well as impaired postural stability and diminished balance. Research from the literature indicates that functional measures, including functional performance, balance and balance confidence, partly mediated the observed association between DPN and lower HRQoL also exercise programs or systematic physical therapy can help people with DPN become more mobile and balanced.[2] Exercise therapy has been proved that to reduce inflammatory markers and improve the physiological state of diabetic patients. In comparison with healthy controls, diabetic patients have higher levels of these markers, such as interleukins (IL) and tumor necrotic factor-alpha (TNF). Strategies to improve balance in DPN patients may lessen their risk of falling and postural dysfunction. Medication, diet, and exercise are the therapies used to manage diabetes. It is well known that exercise training and physical activity improve lipid metabolism, glucose control, and cardiovascular risk factors in people with diabetes. Muscle contraction increases the permeability of the plasma membrane to glucose because it increases the number of glucose transporters, and exercise lowers HbA1c levels. Exercise can reduce HbA1c levels and encourage insulin's effect on glucose metabolism**.[3]**

Type 2 diabetes-related physical impairment is largely caused by poor glucose management and decreased motor conduction. Not every individual with type 2 diabetes experience peripheral neuropathy. 10% of diabetics have neuropathy at diagnosis, and 50% will develop it in the next 25 years. Diabetic neuropathy can be effectively prevented by recognizing risk factors and factors that accelerate the diabetic neuropathy development and regulating them. Elevated blood glucose levels in diabetic patients affect their motor, sensory, and balance receptors. Exercise programs are recommended for people with DPN in order to lower their risk of falling, which effectively maintains independence and improves balance. It has been demonstrated that whole-body vibration improves balance indices in DPN patients. [3]

In DPN, sensory neuropathy is commonly characterized as numbness and prickling sensation that radiates proximally from the feet in a stocking-glove pattern. Exercise intolerance, orthostatic hypotension, and sudden death are symptoms of diabetic autonomic neuropathy, a form of DPN that also affects the autonomic nerve system. The most typical DPN symptoms include tingling, numbness, and discomfort, which might get worse at night. It starts in the toes and moves toward the plantar surfaces of the feet, ankles, and lower shins. It is often accompanied by cramps during the night and instability when walking. DPN gradually reduces normal walking performance and impairs distal muscular strength. The primary cause of postural instability and significant gait variability, which may raise the risk of falls, is peripheral nerve alteration followed by DPN.[4]

The factors that lead to the destruction of neurons and axons in sensory and motor nerves are hyperglycemia, nitrogen and oxidative stress, mitochondrial function disorder, activation of the polyol pathway, increased advanced glycation end product (AGE), and increased irritation symptoms. These factors also affect diabetic peripheral neuropathic pathogens. Diabetic peripheral neuropathy causes nerve damage that follows a certain destructive pattern, including motor nerves after sensory nerves and manifesting as dying-back. This indicates that the lower axons expire before the neurological system (nerve tree) is entirely destroyed. The dying-back pattern appears to be caused by an imbalance or degeneration in the synthesis of proteins and other components required for axons. In longer axons, this pattern is more noticeable.

The axonal transport system moves the materials needed for the cellular body's preservation and operation faster due to the axons' great distance from it. Microtubules, motor kinesin, and dynein proteins are components of this system. Many cell exports are carried out by Kinesin-1, which travels over microtubules using the energy produced by ATP (adenosine triphosphate) hydrolysis. Two kinesin light chains (KLCs) are required to link cell cargoes to kinesin-1. KLC1 plays a crucial part in axonal (nerve) transport and is in charge of joining intercellular cargoes such as cellular mitochondria and proteins.

Patients with neurogenic muscular atrophy observe a deterioration in their muscle strength, speed, and endurance, and their potential performance is also reduced due to neural fatigue. In fact, it appears that the primary cause of walking imbalance and difficulties in diabetic peripheral neuropathy patients is a loss of muscle power in the lower body. This raises the risk of falling and slipping.[5]

Motor unit degeneration and neurogenic muscle atrophy are the outcomes of the axonal transport system dysfunction. It appears that a person's motor axons are more prone to damage as a result of their long-term diabetic peripheral neuropathy, which ultimately leads to increased muscle tissue loss.[6]

Computer based interactive balance training has the mat has four step-sensitive target panels. Patients stand at the center of the mat and make left, right, forward or backward step responses to a sequence of step instructions that are presented on the screen. The Modular Interactive Stepping Tiles was developed by one of the authors and can be arranged in different permutations, as appropriate, so that standing balance and stepping skills in all directions can be practiced with integrated visual feedback about weight taken through each leg and the number of steps taken.[7]

Training of postural control requires appropriate tracking and feedback of performance. Computer based interactive training regimen specifically developed to improve balance. This regimen motivates the user during training. During balance training, participants were presented an interactive virtual reality interface on a computer screen. The ankle joint–based point-to-point reaching task included two circles that appeared sequentially on the screen: a start circle in yellow followed by a target circle in green. By moving the hip joint in the anteroposterior direction through coordination of the upper and lower body, rotation around the ankle joint can be achieved, and, thus, the participants were able to move the square to and fro. Similarly, movement of the red square in the mediolateral direction can be achieved. The participants now performed a series of point-to-point ankle reaching exercises by coordinating upper and lower body movement to move the red square from the start circle to the target circle in a straight line as fast as possible once the green target circle appeared on the screen.

After successfully reaching the target circle, another circle appeared at the initial start position, and participants moved the red square back to the initial circle in the same manner and resumed their upright position.[8]

The purpose of the current study was to ascertain how computer-based interactive balancing training affects the balance and functional status of individual with diabetic neuropathy. Patients with diabetic neuropathy have a higher risk of falling and losing their balance than those without the condition.

MATERIALS/METHODOLOGY

Study Design and study setting: Pre and post Experimental Study conducted in a Department of Neurophysiotherapy, Dr. APJAK COPT, PMT-PIMS, LONI.

Sample Size and Method: A total of 10 participants were selected by conventional sampling.

Study Population: Patients with diabetic neuropathy between the age group of 30-60.

Selection criteria: The inclusion criteria of study included age group between 30-60, Patients having a diagnosis of diabetic neuropathy, both male and female, and those who voluntarily participate in the study are included.

Neurological impairment, any significant vascular complications, severe retinopathy, and lower limb musculoskeletal injuries were among the study's exclusion criteria.

Outcome Measures:

1) Functional Reach test
2) Timed up and go test
3) Computer based Balance board (MFT)

PROCEDURE

The study received ethical clearance by the institutional Ethical Committee of Dr. A.P.J Abdul Kalam college of Physiotherapy, PIMS-DU Reg. no-PIMS/DR.APJAKCOPT/ICE/2024/192. 10 participants were included according to inclusion and criteria. All the participants were explained about the study, and a written informed consent form was signed by each one of them. Care was taken that study should not cause any harm to the patient. A pre-assessment was taken which includes functional reach test and timed up and go test. A two-week intervention was planned. This includes computer based interactive balance training along with conventional exercise. Participants were trained on computer-based balance board. A post-assessment was taken after two weeks. For assessing functional status functional reach test and timed up and go test was used. The efficacy of computer-based interactive balance training and functional status will be determined by the difference between the results of the pre and post assessments. Post data on all outcome measures was collected after two weeks of duration, and analysis was done.

Intervention: The exercises primarily focus on improving balance and improving functional status. Exercise includes: Range of motion exercise, Strengthening exercise, single leg stance,

Tandem leg stance, Tandem walking, Sideways and backward walking, Computer based balance board training. These Exercises were given for two weeks and after that post-assessment was taken to determine the changes after practicing computer based interactive balance training on functional status.

PROTOCOL

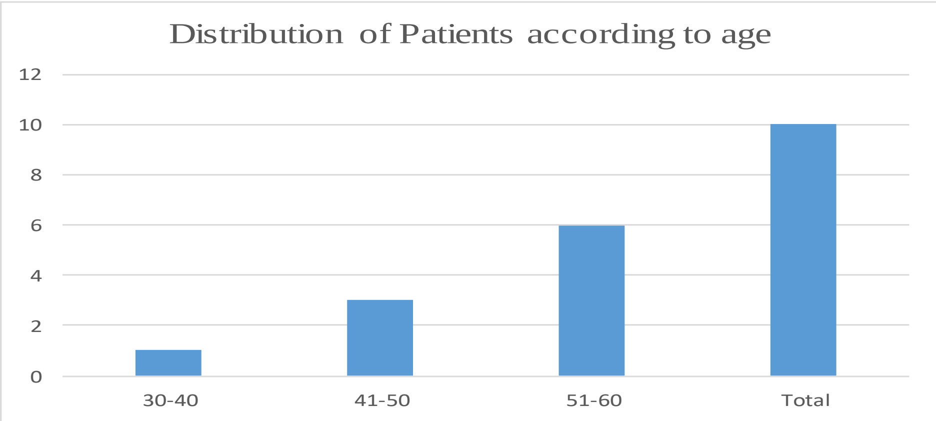
Before starting with the intervention, pre-assessment was taken of all the participants included. After that a 2-week treatment plan was planned. It was given as 1 session per day with the regular conventional physiotherapy for 7 days per week. All sessions began with a 5 min pre-exercise warm-up of gentle stretches and ended with a 5 min cool-down which included slow walking. The intensity of the exercises was gradually increased based on participant performance during the course of the intervention. This session continued for two week and after that post assessment was taken.

DATA ANALYSIS AND RESULTS

Results were analyzed on basis of data obtained pre and post intervention using Graph Pad Instat application. Descriptive statistics for all outcome measures were expressed as mean, standard deviations and test of significance such as paired t test. The study was conducted in Diabetic Neuropathy patients with age Mean±SD value of 50.5±9.04 years which were selected from the Dr. Balasaheb Vikhe Patil rural medical hospital, Loni BK on the basis of inclusion and exclusion criteria. There was total 10 participants of which 6 were males and 4 were females.

Table No:1 Distribution of patients according to age

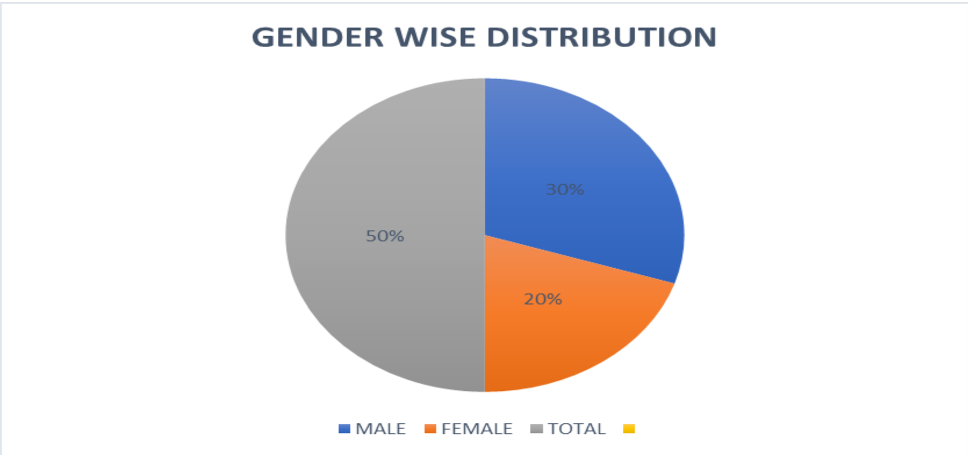
AGE	30-40	41-50	51-60	Total
No of participants	1	3	6	10



Graph No. 1

Table No:2 Gender wise distribution of Participants with Diabetic Neuropathy

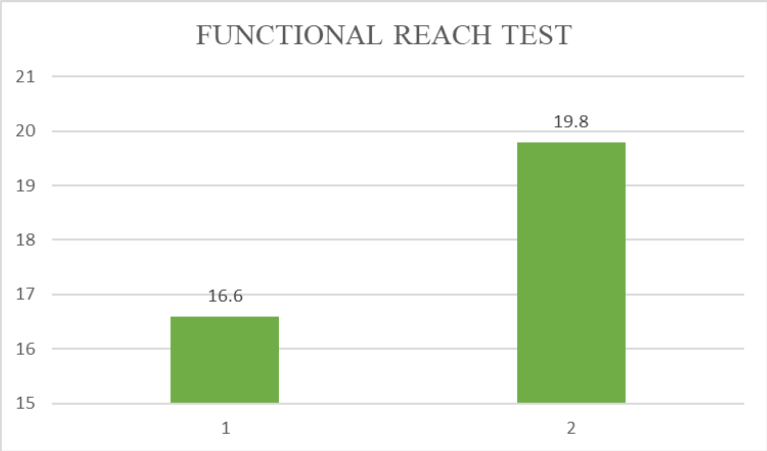
GENDER	NO OF PARTICIPANTS
MALE	6
FEMALE	4
TOTAL	10



GRAPH NO.2

CHART NO 3: FUNCTIONAL REACH TEST

Functional Reach test	Pre-Intervention Mean± SD	Post-Intervention Mean± SD	T value	P value (p<0.001)
	16.6± 2.836	19.8± 2.974	7.686	0.0001 Very Significant



GRAPH NO.3

Pre and post Intervention functional reach test was compared and analyzed with Paired t test.

The pre-Intervention (Mean ± SD) value of functional reach test is 16.6± 2.836 and post-Intervention (Mean ± SD) is 19.8± 2.974. Mean difference of Pre and Post Functional reach test was -3.200 with t-value 7.686 and p-value 0.0001($p<0.001$) which shows very significant difference in pre and post intervention.

CHART NO.4: TIMED UP AND GO TEST

Timed up and go test	Pre-Intervention Mean± SD	Post-Intervention Mean± SD	T value	P value (p<0.001)
	17.1± 5.971	16.8± 5.959	1.964	0.040 Significant

GRAPH NO. 4

Pre and post Intervention timed up and go test was compared and analyzed with Paired t test.

The pre-Intervention (Mean ± SD) value of timed up and go test is 17.1± 5.97 and post-Intervention (Mean ± SD) is 16.8 ± 5.95. Mean difference of Pre and Post Timed up and go test was -0.3000 with t-value 1.964 and p-value 0.040 (p<0.001) which shows significant difference in pre and post intervention.

DISCUSSION

The present study conducted on Effect of computer-based interactive balance training on functional status in individual with diabetic neuropathy. Ten participants were selected to investigate the effect of 2-week computer-based program on balance training and functional status.

This study is an attempt to examine the effects of computer-based balance training on functional status in 10 patients of Diabetic neuropathy with mean age of 50.5±9.04. This study was conducted in Neuro physiotherapy department Dr. APJ AK College of Physiotherapy, Pravara Institute of Medical Sciences, Loni, Ahmednagar.

The pre and post intervention data was collected, analyzed and results were obtained. The results of the study were obtained by pre and post measurements of functional reach test and timed up and go Test. All 10 participants completed 2 weeks of intervention.

No specific study has been done in Diabetic Neuropathy population to find out effect of computer-based interactive balance training on functional status. Therefore, this study can be considered to be novel.

We discussed in our study how computer-based interactive balance training improved the functional status of individuals with diabetic neuropathy.

In our research, the mean ±SD functional reach test score before the intervention was 16.6± 2.836, and two weeks after the intervention, the score was 19.8± 2.974.

Pre- and post-intervention data of functional reach test were compared and analyzed with paired-t test which showed very significant difference with t-value 7.686 and p-value 0.0001. Also, pre-intervention Mean ±SD Timed up and go test was 17.1± 5.97 and after 2 weeks of intervention Timed up and go test is 16.8 ± 5.95. Pre- and post-intervention data of Timed up and go test were compared and analyzed with paired-t test which showed significant difference with t-value 1.964 and p-value 0.040.

This indicates there is significant improvement in functional status i.e. Functional reach test and timed up and go test following 2 weeks of Computer based balance program.

According to a study, patients with diabetic neuropathy whose received two weeks of computer-based balance training observed improvements in their functional status and balance.

As much as 50 percent of people with diabetes have diabetic peripheral neuropathy that is related to damage to the peripheral sensory and motor nerves and is a risk factor for falls on its own. Injuries, psychological distress, and reduced physical activity are among the health consequences of falls that result from Diabetic Peripheral Neuropathy.[22]

Individuals may improve postural instability when standing silently by using visual cues from a fixed visual environment. Individuals tend to become more conscious of their body's orientation and displacements in space when they received more visual information. [23]

By using proprioceptive feedback, a balance board can help activate these sensory pathways. By encouraging users to concentrate on shifting weight and maintaining stability, the interactive nature of the board helps retrain the body and brain to adapt for the lost feeling. The body's postural control system is put to the test by balance boards, particularly when the user must stand, tilt, or move in different directions. Frequent use lowers the risk of falls by enhancing the body's capacity to maintain balance in the face of altered feeling.

Strength and dynamic control are enhanced by the board's interactive features, which promote brain-muscle synergy. Strength and dynamic control are enhanced by the board's interactive features, which promote brain-muscle synergy. This is especially crucial for those with diabetic neuropathy due to poor coordination and weak muscles can worsen problems with balance.

Our intervention was focused on dynamic tasks that involved environmental interaction, reactive balance control, and strength training of the lower limbs. Weight shifting to the left, right, and forward and backward is essential when moving on targets in different directions, this provides a challenge to dynamic balance and functional mobility. Strength and balance training has been shown to be beneficial for patients with DPN in a number of research. These studies have shown that patients' walking speeds rise, their balance and muscle strength significantly improve, and their fear of falling reduces as fewer falls occur. [24]

Balance training based on interactive video game programs is more enjoyable and attractive, and patients are thus more highly motivated to participate in such training activities, thereby increasing both the frequency of practice and the level of attention during training. Therefore, patients are more willing to maintain regular, long-term practice, and they demonstrate higher compliance. The study done by Erica Shih-Wei Hung et.al(2019)The aim of this study to check the Effects of Interactive Video Game-Based Exercise on Balance in Diabetic Patients with Peripheral Neuropathy: An Open-Level, Crossover Pilot Study This study revealed that 6-week balance-based exercise training using the IVGB system had positive effects on functional balance in patients with DPN[25]

The use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear and feel similar to real world objects and events." Participants interact with projected images, maneuver virtual objects and perform activities programmed into the task, giving the user a sense of immersion in the simulated environment. Various forms of feedback are provided through the environment, the most common being visual and auditory, to enhance enjoyment and motor learning through real-time feedback and immediate results. Han Suk Lee et.al conclude that VR training would be helpful in improving functional outcomes with chronic stroke patients such as gait (speed, cadence, 10MWT, 6MWT), balance (BBS, TUG, postural sway), lower limb movement (FMA, RMI), lower limb strength, and lower limb muscle tone**.** [26]

BBS has been recommended as an effective tool for balance and postural stability training in different neurologic diseases. According to Duygu Aktar Reyhanıoglu et al. (2024), Aim of this study was To evaluate the use of a computer-based biodex balance exercise system (BBS) on balance, neuropathic pain, clinical presentation and nerve function in patients with diabetic peripheral neuropathy (DPN) This study demonstrate that computer-based balance training may be an acceptable and successful therapy method to improve the management of neuropathic pain, and the clinical signs and symptoms are comparable to those of diabetic peripheral neuropathy.[21]

Limitation of this study was the sample size was not adequate, there was a shorter duration of the study, no follow-up with the subjects was done to determine whether the effects were still present.

STRENGTH:

A computer-based balance board improve balance in individuals with diabetic neuropathy by providing targeted, interactive exercises that engage the body's proprioceptive system and help strengthen the muscles involved in maintaining balance. Computer based balance board helps in improving neuroplasticity of brain adapts to the challenges posed by sensory deficits, particularly in relation to balance. Computer-based balance boards that offer interactive exercises stimulate these adaptive changes, improving both sensory awareness and motor control, ultimately leading to improved balance and reduced fall risk.

FUTURE SCOPE

It will be necessary to conduct more study on the specific effects of computer-based balancing training on the functional status, fall risk, and quality of life of people with diabetic neuropathy. To establish strong evidence in support of the widespread implementation of such treatments in clinical practice, future research could focus on large, different populations and long-term results.

CONCLUSION

This study concluded that two weeks of the computer based interactive balance programme improve balance and functional status in patients with Diabetic Neuropathy.

Therefore, the null hypothesis is disproved, which states that a computer-based interactive balancing program won't have a major impact on patients with diabetic neuropathy's functional status and balance.

The alternative hypothesis, which states that after two weeks, a computer-based interactive balancing program will significantly impact the functional status and balance of ten patients with diabetic neuropathy, is accepted.

Therefore, computer-based balance training programs can potentially be viewed as supplements to the standard physiotherapy regimen for diabetic neuropathy patients.

Declaration by Authors

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Conflicts of interest: The authors declare no conflict of interest.

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