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Designing and Development of Diabetic Exercise Mat and its Effect on Sensory Motor Dysfunction in Chronic Diabetic Individuals

Gayatri R. Patane, Suraj B. Kanase*

Abstract

Background: Diabetic neuropathy (DN) is one of the most common late complications of diabetic individual. Diabetic peripheral neuropathy causes peripheral sensory loss and motor deterioration. **Objectives:** The objectives of the study were to find the effect of conventional exercises on designed mat for sensory and motor dysfunction in chronic diabetic individuals. **Materials and Methods:** An experimental study was carried out using simple random sampling method during 1 year in Krishna Hospital. A total of 44 subjects were allocated into Groups A and B to receive conventional physiotherapy and exercise on designed mat, respectively. Protocol was conducted for 3 days per week for 6 weeks. Pre- and post-design was used for assessing the study. **Results:** Subjects were assessed for quantitative sensory testing (QST) and manual muscle testing (MMT). Between the groups, the QST values were for Groups A 4.40 ± 0.66 and B 3.59 ± 1.18 along with $P = 0.0071$. MMT ankle dorsiflexion values were for Groups A 4.27 ± 0.55 and B 3.90 ± 0.61 along with $P < 0.044$, ankle plantar flexion values were for Groups A 4.31 ± 0.47 and B 3.95 ± 0.65 along with $P = 0.04$. Wrist flexion values were for Groups A 4.18 ± 0.50 and B 4.50 ± 0.51 along with $P = 0.04$. Wrist extension values were for Groups A 3.90 ± 0.61 and B 4.50 ± 0.59 with $P = 0.002$. **Conclusion:** This study concluded that both conventional exercises and exercise on designed mat showed significant improvement on QST and MMT. Thus, the study provided the evidence to support that exercises on designed mat are found to be more effective than conventional exercises.

Keywords: Diabetic exercise mat, Diabetic neuropathy, Sensory motor dysfunction

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Introduction

Diabetes mellitus is a group of metabolic disease which is characterized by hyperglycemia which results from insulin secretion and insulin action defects.[1] Prevalence rate of diabetes in age group of 18–99 years is 451 million cases and is expected to be increased by 629 million in 20–79 years by 2045.[2] The incidence of diabetes increases with age with most cases being diagnosed after age of 40 years.[1,3] As diabetic mellitus, in hyperglycemia, results in long-term damage, dysfunction and organ failure of eyes, kidneys, heart and blood vessels,[4] and the most common late complication, diabetic neuropathy (DN). DN is the presence of signs and symptoms of peripheral nerve dysfunction in people with diabetes.[5] Among diabetic individuals, the prevalence of diabetic peripheral neuropathy was 30.3%.[6] Neuropathy is one of the most frequent and disabling complications of diabetes mellitus.[7] Diabetic peripheral neuropathy also called as distal symmetric peripheral neuropathy which is a peripheral nerve disorder that reduces nerve function progressively and results in motor weakening, sensory disorder, and autonomic and tendon reflexes weakening which can be acute or chronic.[8] Diabetic peripheral neuropathy causes peripheral sensory loss in feet and motor deterioration. This sensory loss alters the gait biomechanics, thus affecting balance and increases risk of fall. Deterioration of muscle strength becomes more severe with the development of diabetic peripheral neuropathy. Proximal (knee flexors and extensors) and distal (ankle dorsiflexors and plantar flexors) segments of lower limbs are affected majorly.[9] Quality of support surface and orientation information is carried out through mechanoreceptors in skin and pressure receptors along with proprioceptors such as muscle spindle, GTO, and joint receptors provide information about one's orientation and body movements in somatosensory system.[10] Somatosensory dysfunction in lower limb triggers decrease in ankle position/proprioception and vibration sense. Through mechanism of peripheral nerve damage, hyperglycemia causes somatosensory dysfunction which may increase the risk of injury due to reduced sensation leading to increase in risk of fall, ulceration, and amputation.[11] Somatosensory stimulation plays an important role in increasing the sensitivity of sensory receptors in legs, thus improving quality of sensory input. Thus to improve the quality of sensory input, different exercise surfaces stimulate cutaneous receptors related to deep sensation which is caused by receptors in joints and muscles.[12] In medical management, most frequently used oral drugs for the symptomatic treatment of diabetes and non-diabetics painful neuropathy are tricyclic antidepressant, gabapentin, Cymbalta, and opioids.[13] Glycemia control to be done while managing the diabetes. Thus, despite the control, over 40% of patients with diabetes develop neuropathy and other are driving nerve injury. Non-insulin

Department of Neurosciences, Krishna College of Physiotherapy, Krishna Institute of Medical Science (Deemed to be University) Malkapur, Maharashtra, India

Corresponding Author: Dr. Suraj B. Kanase, Department of Neurosciences, Krishna College of Physiotherapy, Krishna Institute of Medical Science (Deemed to be University), Karad, Malkapur, Maharashtra, India. E-mail: drsurajkanase7@rediffmail.com

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therapies such as Biguanides, Sulfonylureas, GLP-1 receptor agonists, Pramlinitide, SGLT-2 inhibitors are used for treatment of diabetic neuropathy. [14] Physiotherapy plays an important role in the treatment and prevention of DN. Specific exercises programs such as ROM, muscle strengthening, and gait training have being included to maintain or improve gait pattern, mobility, and strength. Proper physiotherapy treatment will help to decrease the symptoms of DN and also improve quality of life. Conventional Physiotherapeutic exercises for treatment of Diabetic Neuropathy included range of motion exercises for upper and lower limbs along with other exercise such as strengthening exercise, wobble board exercises, functional balance exercises, vestibular exercises as well as proprioceptive and gait training were also included. Review shows that individuals with diabetic peripheral neuropathy can improve their balance with aerobic exercise, flexibility exercises, gait training strategies, and strength training exercise.[15-18] Electrotherapeutic modalities are available for DN such as TENS, infrared lamp, and low-intensity laser therapy. It was found in earlier studies that TENS was effective in reducing pain in DN.[13]

The previous studies have shown the effect of various types of intervention on the basis of various components of motor and sensory integration but it was carried out among diabetic patients with mild-to-moderate peripheral neuropathy with single texture mat and the effect was for short period of time. Both therapist and the patient were involved during the treatment protocol which was time consuming as the activities such as standing and walking required somatosensory feedback to identify body's position and environment for attaining planned, purposeful bodily positions.[10] In a study, in diabetic polyneuropathy individuals, vibrotactile sensation was improved with the use of vibromedical insoles on pressure and vibration sensation. It consists of medical insole and vibratory system, and pressure and vibration were evaluated while walking and proved beneficial.[19] Various studies have designed patient-specific insoles such as metatarsal pad, longitudinal arch support, and vibratory motors. It states that application of sub-threshold mechanical stimulates foot mechanoreceptors thereby, improving postural control. Somatosensory information plays an important role in improving postural control, balance and provides stability. Somatosensory stimulation is also done through provision of synthetic grass mat which stimulates the cutaneous and subcutaneous receptors.[12] Somatosensory input stimulates cutaneous receptors in feet relating to deep sensation. Use of multiple textures stimulates the use of muscle- and joint-related information such as sensation of position, velocity, and touch.

Till date, a variety of sensory and motor integration approaches were available. Furthermore, modifications regarding plantar pressure along with vibrotactile in sloes have been customized but its long-term relation to strength and sensory motor dysfunction is limited. Furthermore, it is limited to the usage of single texture along with conventional exercises and management. However, multiple textures such as fur, jute, cotton, hard, and soft textures compiled in a single designed diabetic mat can aid the patient in achieving multisensory and motor function. Active involvement of the patient while performing exercises on the single designed diabetic mat can help the patient in adjusting body weight, posture, and balance. Again, however, literature is limited in usage of multisensory textures on sensory and motor dysfunction. Many studies have done on improving balance and postural stability in DPN but long-term effects on sensory and motor function need clinical evidence. Hence, re-education with a single designed diabetic mat with multiple textures puts an emphasis on improving sensory motor integration and preventing its long-term effects and further progression of DPN.

Materials and Methods

An ethical clearance was taken from the Institutional Ethics Committee of KIMSDU, Karad, before initiation of the study. After that, concerning subjects with chronic diabetic were approached. The purpose of the study was explained and written consent was taken from subjects willing to participate. Subjects were selected for the study according to the selection criteria. Inclusion criteria were DN individuals with impaired sensation, DN individuals with motor dysfunction, age 45–65 years, and having diabetes more than 10 years, both male and female, patients willing to participate exclusion criteria were open wounds, ulcer, pregnancy amputation, and cardiac arrhythmias. Included participants were divided into two groups by convenient sampling method followed by simple random sampling. After inclusion, the procedure was explained. Before initiation of exercises, Michigan neuropathy screening instrument questionnaire was taken. Group A was conventional group and Group B was experimental group. Group B has received exercise on designed mat (toe curls, bipedal toe and heel raises, spot marching, squatting, single limb stance walking, hand stroking, weight shifting on hand, hand tapping, and quadripod). Subjects received treatment for 6 weeks 3 times/week with warm up and cool down exercises. Pre- and post-assessment was done using quantitative sensory testing (QST) and manual muscle testing (MMT).[20-22] These measures were taken before the treatment and after 6 weeks of the treatment. The effect of the treatment given to each group was noted immediately using the outcome measures. The experimental result was statistically analyzed using the Statistical Package for the Social Sciences (SPSS) software. After the general characteristics of the subjects were determined, the paired *t*-test was used to compare the changes between pre- and post-interventions within each group. The significant difference between the two groups was investigated with the unpaired *t*-test.

Results

Statistical Analysis

The outcome measures were assessed at the baseline before the treatment and 6 weeks after the treatment. The statistical analysis was done using unpaired *t*-test and SPSS software.

Discussion

Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion and insulin action.[1] There are long-term damage, dysfunction, and organ failure, especially of eyes, kidney, nerves, and heart and blood vessels were seen in chronic hyperglycemia.[4]

Diabetic peripheral neuropathy is a microvascular complication that affects 47% of people with diabetes mellitus.[23] The main cause of neurological disorders is hyperglycemia as a result of impaired fasting glucose and impaired glucose tolerance. Neurological disorders cause somatosensory dysfunction. Hyperglycemia causes somatosensory dysfunction through the mechanism of peripheral nerve damage. Somatosensory dysfunction in the lower limb decreases ankle position, proprioception, and vibration senses.[12]

In this study, exercises were given on a designed diabetic exercise mat. The mat used in this study is a combination of six different textures combined into a single mat. It proved effective in improving the sensory as well as motor dysfunction. Along with different textures, conventional therapeutic exercise was given and effect was seen. Furthermore, the designed mat proved to be time convenient. The present study carried out among chronic diabetic individuals. Mat training involved the patient individually, so there was active participation of the patient.

The components in this study include balance training, strengthening exercises, stability exercises, flexibility exercises, proprioceptive stimulation, and somatosensory stimulation which were used to see the outcome.

In this study, 44 subjects (20 males, 24 females) diagnosed with diabetic neuropathy were included. Subjects were selected as per the inclusion criteria were age 45–65 years.

Subjects were analyzed and divided into two groups according to convenient sampling followed by simple random sampling method; 44 subjects were divided into two groups. Group A receives the conventional exercises and Group B receives conventional exercise on designed MAT. Treatment protocol was conducted for 3 days per week for 6 weeks. It was carried out for 40–45 min of duration with warm up and cool down session. The study was carried out and the result for sensory as well as motor component by QST and MMT, respectively.

Hence, in the present study, we found out the effect of designing and development of diabetic exercise MAT and its effect on sensory motor dysfunction in chronic diabetics individuals.

Somatosensory input that derives from the feet due to the different exercise surface stimulates cutaneous receptors relating to deep sensation. Receptors present in the joints and muscle causes deep sensation. Motion-related information such as sensations of position and velocity and touch are formed by interaction of joint and muscle. Provision of continuous exercise will stimulate muscle spindle receptor. Muscle spindle is a major factor of proprioceptive development in the ankle joint. Somatosensory stimulation plays a role in increasing the sensitivity of the sensory receptors in the legs because with the increase in sensory input quality.[12]

In our study, QST was used as an outcome measure. In Group A, post-interventional value of QST was 4.40 ± 0.66 and Group B post-interventional QST was 3.59 ± 1.18. The post-intervention assessment shows that there was very significant difference in between Groups A and B ($t = 2.82$, $P < 0.0071$) [Table 1].

In our study, MMT was used as an outcome measure. For ankle dorsiflexion, in Group A, post-interventional value was 4.27 ± 0.55 both the right and left sides. In Group B, post-interventional value was 3.90 ± 0.61 both the right and left sides. The post-intervention assessment shows that there was a significant difference in between Groups A and B ($P < 0.044$, $t = 2.07$) [Table 2].

For ankle plantar flexion in Group A, post-interventional value was 4.31 ± 0.47 both the right and left sides. In Group B, the post-interventional value was 3.95 ± 0.65 both the right and left sides. In Groups A and B, the values were compared by applying the unpaired *t*-test. The post-intervention assessment shows that there was a significant difference in between Groups A and B ($P = 0.04$, $t = 2.11$) [Table 3].

For wrist flexion in Group A, post-interventional value was 4.18 ± 0.50 both the right and left sides; in Group B, post-interventional value was 4.50 ± 0.51 both the right and left sides. The post-intervention assessment shows that there is a significant difference in between Groups A and B ($P = 0.04$, $t = 2.08$) [Table 4].

For wrist extension in Group A, post-interventional value of wrist extension was 3.90 ± 0.61 both the right and left sides. In Group B, post-interventional value was 4.50 ± 0.59 both the right and left sides. In Groups A and B, the values were compared by applying the unpaired *t*-test. The post-intervention assessment shows that there was very significant difference in between Groups A and B ($P = 0.002$, $t = 3.24$) [Table 5].

In this study, it noted that increased in sensation and improve the muscle strength as well as improve the quality of life of diabetic individuals.

Table 1: Comparison of QST between the groups

Parameter	*Post Group A intervention Mean±SD*	*Post Group B intervention Mean±SD*	*P-value*	*t-value*	*Interference*
QST	4.40±0.66	3.59±1.18	0.0071	2.82	Very significant

QST: Quantitative sensory testing, SD: Standard deviation

Table 2: Comparison of MMT dorsiflexion between the groups

Post values of dorsiflexion	*Group A*		*Group B*	
	Right	*Left*	*Right*	*Left*
Mean±SD	4.27±0.55	4.27±0.55	3.90±0.61	3.90±0.61
t-value	2.07		2.07	
P-value	<0.044		<0.044	
Interpretation	Significant		Significant	

MMT: Manual muscle testing, SD: Standard deviation

Table 3: Comparison of MMT plantar flexion between the groups

Post values of plantar flexion	*Group A*		*Group B*	
	Right	*Left*	*Right*	*Left*
Mean±SD	4.31±0.47	4.31±0.47	3.95±0.65	3.95±0.65
t-value	2.11		2.11	
P-value	0.04		0.04	
Interpretation	Significant		Significant	

MMT: Manual muscle testing, SD: Standard deviation

Table 4: Comparison of MMT wrist flexion between the groups

Post values of wrist flexion	*Group A*		*Group B*	
	Right	*Left*	*Right*	*Left*
Mean±SD	4.18±0.50	4.18±0.50	4.50±0.51	4.50±0.51
t-value	2.08		2.08	
P-value	0.04		0.04	
Interpretation	Significant		Significant	

MMT: Manual muscle testing, SD: Standard deviation

Table 5: Comparison of MMT wrist extension between the groups

Post values of wrist extension	*Group A*		*Group B*	
	Right	*Left*	*Right*	*Left*
Mean±SD	3.90±0.61	3.90±0.61	4.50±0.59	4.50±0.59
t-value	3.24		3.24	
P-value	0.002		0.002	
Interpretation	Very significant		Very significant	

MMT: Manual muscle testing, SD: Standard deviation

While there was a significant result in the experimental group out of conventional group as designed mat is used in the experimental group, whereas the conventional group was given exercises on floor.

In this combined sensory motor interventional study, we found that while the participant perceived sensory dysfunction and muscle weakness from DN improves, they felt hindered in certain aspect of their life by painful neuropathy after 6 weeks of exercise on mat.

The result of the current study showed that DN can be reduced by both the treatments that are conventional physiotherapy exercises as well as exercise on designed mat. However, exercise on designed mat was more effective than conventional exercises clinically and statistically as multisensory re-education along with exercise was conducted in chronic diabetic individuals with improved tactile sensation and proprioception.

Conclusion

This study concluded that both conventional exercises and exercise on designed mat are significant improvement on QST and MMT.

Thus, the study provided the evidence to support that exercises on designed mat are found to be more effective than conventional exercises.

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References

1. Ozougwu JC, Obimba KC, Belonwu CD, Unakalamba CB. The pathogenesis and pathophysiology of Type 1 and Type 2 diabetes mellitus. J Physiol Pathophysiol 2013;4:46-57.
2. Sowjanya M, Sanjeev A. Significance of sensory specific intervention on balance in Type 2 peripheral diabetic neuropathy individuals. Int J Health Sci Res 2019;9:47-51.
3. Chan JC, Malik V, Jia W, Kadowaki T, Yajnik CS, Yoon KH, *et al*. Diabetes in Asia; epidemiology, risk factors, and pathophysiology. JAMA 2009;301:2129-40.
4. Thomas N, Kapoor N, Velavan J, Vasan SK. A Practical Guide Diabetes Mellitus. 8th ed. New Delhi: Jaypee Brothers Medical Publishers (P) Ltd.; 2018.
5. Boulton AJ, Malik RA. New Concepts in Diabetes and its Treatment: Diabetes Neuropathy. Karger: 2020.
6. Gous SS, Suhailetcl M. Study of prevalence of diabetic peripheral neuropathy and associated risk factors in type diabetes patients attending diabetic care centre in Maharashtra. Int J Recent Trends Sci Technol 2015;16:620-3.
7. Dejgaard A. Pathophysiology and treatment of diabetic neuropathy. Diabet Med 1998;15:97-112.
8. Awaluddin SW, Ardi M. The effects of foot exercise to distal sensorimotor on diabetic peripheral neuropathy. Indian J Forensic Med Toxicol 2019;13:1793-8.
9. Reeves ND, Orlando G, Brown SJ. Sensory-motor mechanisms increasing falls risk in diabetic peripheral neuropathy. Medicina 2021;57:457.
10. Thompson LA, Savadkoohi M, de Paiva GV, Brusamolin JA, Guise J, Suh P, *et al*. Sensory integration training improves balance in older individuals. Annu Int Conf IEEE Eng Med Biol Soc 2020;2020:3811-4.
11. Majeedkutty NA, Jabbar MA. Physical therapy for diabetic peripheral neuropathy: A narrative review. Disabil CBR Inclusive Dev 2019;30:112-25.
12. Sativani Z, Purwanto B, Dwikora NU. Effects of Balance Exercise and Somatosensory Stimulation on Somatosensory Response in Diabetic Peripheral Neuropathy. Proceeding of Surabaya International Health Conference; 2017.
13. Patel BR, Kadam N, Pawar P. Effect of Rood's Approach in Diabetic Polyneuropathy: Biomedical Research. Biomedical Research; 2019.
14. Mario S. Diabetes Mellitus Treatment. Cleveland, Ohio: The Cleveland Clinic Foundation; 2018.
15. Zakaria HM, Hassan S. Effectiveness of multi-sensory stimulation approach on balance outcome in diabetic neuropathic patients. Bull Facult Phys Ther 2008;13:301-8.
16. El-Wishy A, Elsayed E. Effect of proprioceptive training program on balance in patients with diabetic neuropathy: A controlled randomized study. Bull Facult Pharm Cairo Univ 2012;17:1-8.
17. Mueller MJ, Tuttle LJ, Lemaster JW, Strube MJ, McGill JB, Hastings MK, *et al*. Weight-bearing versus nonweight-bearing exercise for persons with diabetes and peripheral neuropathy: A randomized controlled trial. Arch Phys Med Rehabil 2013;94:829-38.
18. Richardson JK, Sandman D, Vela S. A focused exercise regimen improves clinical measures of balance in patients with peripheral neuropathy. Arch Phys Med Rehabil 2001;82:205-9.
19. Cahm MB, Aalietal M. The effects of vibro-medical insole on vibrotactile sensation in diabetic patients with mild-to-moderate peripheral neuropathy. Neurol Sci 2018;39:1079-84.
20. Siao P, Cros DP. Quantitative sensory testing. Phys Med Rehabil Clin North Am 2003;14:261-86.
21. Magee DJ. Orthopaedic Physical Assessment. 6th ed., Vol. 33. Amsterdam, Netherlands: Elsevier India; 2014.
22. Jain PS, Kanase SB. Effectiveness of Sensory Motor Integration in Diabetic Ployneuropathy. Tathapi: 2020.
23. Dyck PJ, Herrmann DN, Staff NP, Dyck PJ. Assessing decreased sensation and increased sensory phenomena in diabetic polyneuropathies. Diabetes 2013;62:3677-86.