Effects of Multisensory Training on Balance and Gait in Persons with Type 2 Diabetes: A Randomised Controlled Trial

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ABSTRACT

Purpose: *Progressive deterioration of physical function occurs in persons with Type 2 diabetes and peripheral neuropathy. This study assessed the effects of multisensory training on balance and gait in persons with diabetic neuropathies.*

Method: *Thirty two persons with peripheral neuropathies were enrolled, randomised, and subdivided into 2 groups - an experimental group of 16 participants with diabetes (65 ± 2.12 years) and a control group of 16 participants with diabetes (68 ± 2.17 years). For 6 weeks, both groups were given health education on diabetes for 30 minutes a week. In addition, the experimental group practised a multisensory exercise programme for 30 minutes, 3 times a week over 6 weeks. Outcome measures used were 'timed up and go' test for assessing balance and '6-minute walk' test for gait. Standard descriptive statistics were used to report means, standard deviation, and range for baseline characteristics. Paired and unpaired 't-tests' were used wherever necessary, to determine significant differences in data among groups and between pre-test and post-test scores (p<0.05).*

Results: *By the end of the trial period, the intervention group showed a significant improvement in scores of the 'timed up and go' test (t= 14.7092), but there was no statistically significant difference in the '6-minute walk' test scores (p=0.7206, t= 0.3644).There was no difference for both measures in the control group.*

Conclusion: *The study showed that multisensory exercises could improve balance in persons with Type 2 diabetes and peripheral neuropathy. The findings*

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suggest that along with physiological sensory factors, cognitive-behavioural factors and strengthening of the lower limb muscles should be considered when treating diabetic persons with gait alterations.

***Key words**: Balance, gait, multisensory training, type 2 diabetes.*

INTRODUCTION

Diabetes mellitus (DM) is emerging as a pandemic, with high social and economic costs. India has the highest number of diabetics of all the countries in the world, with over 30 million people now diagnosed with diabetes (Diabetes.co.uk). Type 2 diabetes mellitus and its common complication, peripheral neuropathy, affect a large population (World Health Organisation, 1999). Peripheral neuropathy (PN) leads to sensory and motor deficits, which often result in mobility-related dysfunction and alterations in gait characteristics (Allet et al, 2010). Diabetic persons with peripheral neuropathy have lower gait velocity, decreased cadence, shorter stride length, increased stance time and higher step to step variability compared with healthy controls. These gait alterations increase on irregular surfaces. Allet et al (2009) also found lower limb strength, fear of falling and sensory problems to be related to spatiotemporal gait alterations. Additionally, persons with peripheral neuropathy show postural instability with a larger centre of pressure displacement, higher sway area and greater instability when standing still with eyes closed (Lafond et al, 2004). Simoneau et al (1994) reported that postural instability was further found to be significantly associated with sensory neuropathy.

Walking and balance are both critical for independence in activities of daily living (Prasansuk et al, 2004). Recent studies show that people with diabetes are 15 times more likely to fall when walking than those in the same age-matched population of people without diabetes (Dingwell & Cavanagh, 2001). The prevalence of DM increases with age (Sharma et al, 2011). Complications commonly associated with diabetes include vascular disease, micro-vascular complications of the kidney, nervous system and vision. However, diabetes can also lead to other disturbances including a loss of balance (Hiltunen, 2001). Balance is a complex process which requires input from the afferent receptor systems, vestibular, visual, proprioception, and general exterosensibility, in order to generate a motor response allowing the transition between dynamic and static activities (Woollacott & Shumway-Cook, 2002). The loss of somatosensation, especially of plantar cutaneous sensation, is believed to be primarily responsible for a host of specific PN-related movement disturbances observed in weight-bearing situations.

Individuals with PN exhibit reduced physical activity, standing balance, mobility and independence. They walk 20-30% slower than age-matched healthy controls. It has been demonstrated that those with greater PN-related loss of plantar cutaneous sensation tend to move with slower preferred walking speed (PWS). It has therefore been argued that this "cautious" gait strategy is the primary compensatory mechanism employed to maintain safe walking patterns under conditions of reduced sensation (Menz et al, 2004). PN can interrupt the afferent and efferent functions of the lower extremities that are responsible for maintaining normal posture and normal walking. In consequence, proprioception is lost. When there is a decrease in sensitivity of the sole of the foot and in the information coming from mechanoreceptors, balance declines in the elderly and in persons with diabetes. No definitive treatment for diabetic neuropathies has been reported, and very few studies have been published on the role of exercise in reducing either the symptoms or incidence of diabetic neuropathies. Only a few studies have evaluated treatments that aim to improve gait and balance, and decrease fall risk (Petrofsky, 2006). Separate somatosensory, visual and vestibular inputs comprise the primary sources of information that contribute to postural orientation. The process of melding these three distinct senses into a single unified perception of body-in-space is "sensory integration". Multisensory intervention emphasises the stimuli to sensory systems.

Several studies have shown that training has positive effects on gait speed, postural stability and mobility of elderly individuals. In addition, a study by Alfieri et al (2010) on functional mobility and balance in community-dwelling elderly who submitted to multisensory exercises showed that there was significant control of balance and dynamic activities.

A better understanding of gait and balance may represent an important aspect of diabetes management for safety. Since elderly people often demonstrate symptoms similar to those of diabetic persons (i.e., de-conditioning, muscle weakness, decreased joint mobility and decreased foot sensibility), it was assumed that programmes developed for the elderly might also improve the gait and balance of diabetic persons. Therefore, this study aimed to evaluate the effect of multisensory exercise training on the gait and balance of persons with diabetes.

Objectives

In India, though many studies on exercise-facilitated rehabilitation in Type 2 diabetes have been done, the authors were not aware of any previous randomised controlled trial. The objective of this study was to determine the effects of 6-week multisensory training on balance and gait in persons with Type 2 diabetes.

METHOD

This randomised controlled prospective trial, using an intervention group and a control group, was conducted at A.M. Physiotherapy Centre in Kerala, India. The study was approved by the local Ethics Committee. A sample of 32 diabetic persons was recruited. 16 of them were allocated to the intervention group and 16 to the control group. All the subjects who consented to participate in the study were males, aged between 55 and 75 years, with Body Mass Index between 20 and 30.

Only persons who were diagnosed with Type 2 diabetes by the physician were included. Those without medical contraindications for engaging in physical activity and with clinically diagnosed diabetic peripheral neuropathy were enrolled. The other inclusion criterion was the ability to walk for 6 minutes continuously and unassisted. Exclusion criteria were: persons with concomitant foot ulcers, orthopaedic or surgical problems affecting gait variables, non-diabetic neuropathy, and other neurological pathologies (other than PN) that could influence gait variables. Those who were involved in regular physical training during the previous 3 months were excluded. People with any uncontrolled cardiovascular, respiratory disorder, visual impairment without correction, recent complaints of dizziness or falls were also excluded from the study. A randomisation list was electronically generated and was used by an individual not involved in either the recruitment, evaluation or treatment processes.

Those who agreed to participate in the study were contacted by the researchers and given individual appointments, at which time the informed consent document was signed and baseline evaluation performed. After participants underwent a clinical examination, a gait analysis and balance test, they were randomly allocated to either the intervention group or the control group. All outcome measures were assessed at baseline, after 6 weeks.

Test Description and Measures

The participants were tested before and after 6 weeks of the study. *Both groups underwent the following tests*:

1. 'Timed Up and Go' Test

The 'Timed Up and Go' test (TUG-test) is an effective method for assessing mobility and quantifying locomotor performance, including a sequence of functional manoeuvres used in everyday life. Basic mobility skills are tested, such as rising from a chair, walking 3 metres, turning and sitting down on the same chair. A stopwatch is used to time the test (in seconds). The test is convenient in clinical settings as it is quick, requires no special equipment or training, and is easily included as part of the routine medical examination. TUG was proven to have good inter-rater reliability (ICC = 0.99) (Steffen et al, 2002).

Good test-retest reliability (ICC = 0.97–0.99 and Spearman's = 0.93) have been demonstrated in many studies.

2. 'Six-Minute Walk' Test

The 'Six-Minute Walk' Test (6MWT), a measure of the distance a person walks in 6 minutes, was used to assess overall physical performance. Subjects were asked to cover as much distance as possible within 6 minutes, without running. The 6MWT has been shown to be reliable and valid in detecting differences in mobility performance and has high test-retest reliability (Steffen et al, 2002).

Treatment Description

The experimental group was submitted to multisensory exercise training thrice a week for 30 minutes, over 6 weeks. Exercise interventions, in the form of multisensory exercise programmes, are now recognised as a new strategy to improve physical function. At present, since no specific gait and balance programme is offered to persons with diabetes, the control group received no treatment. Both groups received health education on diabetes for 30 minutes each week, for 6 weeks. The intervention group and control group were allowed to continue their usual leisure activities. Participants were instructed to report any symptom or feeling of falling during the exercise session. The therapist stood beside the participant to guarantee physical safety in case of loss of balance. A 5- minute warm-up before the activity included short walks and games with balls, using hands or feet. Participants were asked to walk forwards, backwards, and sideways, with eyes both open and closed, at different speeds and for various distances. Ground surfaces also varied and included mattresses and foam rubber, apart from the regular floor. This session lasted for 15 minutes - 5 minutes each on the floor, the mattress and the foam pad. A high-density closed cell foam pad was used in this study, like other similar studies (Steele, 1992; Hill et al, 1997), to alter the proprioceptive feedback from the support surface and create a more dynamic task.

Participants also faced challenges from obstacles such as ropes, cones, and sticks. According to individual ability, the participants were asked to remain standing on unipedal or bipedal support with eyes open or closed. As part of the multisensory training, they performed exercises under the following conditions: (1) eyes open, firm surface; (2) eyes open, soft surface; (3) eyes closed, firm surface; and (4) eyes closed, soft surface. The exercises included: performing double-legged stance for 10 seconds, performing tandem stance for 10 seconds, and rising from a chair without the use of arms; walking forwards and backwards with a tandem walking pattern (toes of one foot touching the heel of the foot in front); and performing single legged stance for 10 seconds. This final session lasted for 10 minutes.

Data Analysis

Using Microsoft Excel, data was converted into SPSS (Statistical Package for Social Sciences) format for analysis. SPSS version 19 was used. The descriptive statistics were first calculated and the distribution of data was checked.

RESULTS

Statistical analysis was done using independent 't-test' to compare the descriptive characteristics (age, height, weight) and no statistically significant difference was found. The significance level was set at 0.05. The results of unpaired 't-test' with mean showed the homogeneity of two groups (Table1).

Table: 1 Analysis of Baseline Characteristics

Variable	MSE Training Group	Control Group	Significance
Age	65 ± 2.12	68 ± 2.17	>0.05
Height (cm)	163.95 ± 10.32	165.59 ± 7.44	>0.05
Weight (kg)	72.35 ± 10.17	76.28 ± 16.90	>0.05
BMI	26.86 ± 4.34	27.74 ± 5.97	>0.05

The pre-test values of the control group and the multisensory training group were compared using unpaired 't- test' (time in seconds).By conventional criteria, this difference is considered to be not statistically significant (p= 0.3231) (Table 2). The pre-test and post-test values of multisensory training group were compared using paired 't- test' (time in seconds).By conventional criteria, this difference is considered to be statistically significant (p <0.0001) (Table 2).

Table 2: Analysis of pre- and post- test scores of 'Timed Up and Go' test

Group	Pre-test TUG	Post-test TUG	t
Experimental group	13.317 ± 0.865	11.242 ± 1.086	t = 14.7092
Control group	13.325 ± 0.865	13.067 ± 0.925	t = 0.9989

There was no statistically significant difference in the TUG scores of the control group. The scores obtained from the 'six- minute walk' test were analysed using paired and unpaired tests wherever necessary. The comparisons of pre- and post-values of 6MWT in the multisensory exercise group were found to be statistically not significant. The two-tailed 'p' value equals 0.7206. By conventional criteria, this difference is considered to be not statistically significant (t = 0.3644) (Table 3).

Table 3: Analysis of pre- and post- test scores of 'Six-Minute Walk' test

Group	Pre-test 6MWT	Post-test 6MWT	p value	t
Experimental group	416.52 ± 8.72	417.59 ± 7.42	0.7206	t = 0.3644
Control group	420.79 ± 10.82	422.16 ± 11.12	0.7699	t = 0.2979

DISCUSSION

The results show that the groups were similar in baseline characteristics. After intervention, the multisensory exercise group showed significant improvement in the TUG scores, from 13.317 ± 0.865 seconds to 11.242 ± 1.086 seconds (t= 14.7092). The pre-test and post-test scores showed no statistically significant difference in the 'Six-Minute Walk' test scores of the group given multisensory exercises. The difference in distance covered in six minutes changed from 416.5200 ± 8.7200 metres to 417.596 ± 7.4239 metres only (t = 0.3644).The control group showed no statistically significant difference in both outcome measures.

A growing number of studies have shown that exercises have some effect on balance. In this study, results revealed that balance improved significantly after the 6-week multisensory exercise training. The multisensory training conducted in a group might have contributed to the improvement in balance. Akin to this study, Robitaille et al (2005) showed that exercise programmes performed in groups improved the balance of the elderly in the community. Wayne et al (2004) reported that the improvement of vestibular function and the possible linkage of psychological well-being may probably be the adjuvant mechanism of balance improvement.

Nashner et al (1988) found that there is a close interaction between sensory and motor processes in postural control, since the type of postural movement used necessarily affects the types of sensory information available during postural control. Thus, the type of postural movement used may depend not only on the mechanical constraints of the task but also on the availability of sensory information. Somatosensory, vestibular and visual sensors are located in different parts of the body, such that a different combination of sensory information is available when subjects use 'the hip versus the ankle' strategy for postural correction (Winter, 1995). The loss of sensory information can bring about changes in the use of the ankle and hip strategies. This suggests that selection of postural movement strategies appears to be an automatic proactive process, dependent upon accurate multisensory information that assures forms of postural movement appropriate for the environmental conditions. The results of this study suggest that these compensatory mechanisms can be improved with proper sensory training. When the surface conditions are unstable, visual and vestibular inputs become more important than usual because the amount of accurate, available information from the proprioceptive system is reduced (Shumway-Cook et al, 2000). These authors found that peripheral sensory information is used by lower levels of the CNS to trigger automatic postural reactions, and by higher levels of the CNS to develop internal representations of the self in space for the generation of anticipatory postural responses and voluntary movements.

There was no statistically significant difference in the scores of 6MWT in the intervention group that submitted to multisensory exercise training. The achieved gain in distance in the 6 MWT in patients of the multisensory training group was minimal, from 416.52 ± 8.72 metres to

417.59 ± 7.42 metres. It has been demonstrated that older persons with Type 2 diabetes had accelerated loss of muscle strength over time, suggesting an additional biological mechanism to explain the association between diabetes and poor physical function (Park et al, 2009). The potential physical decrease observed with ageing is partly due to reduced muscle mass, strength, and endurance, thus defining sarcopenia. Indeed, after 40 years of age, muscle mass decreases by an average of 5% per decade.

Van Deursen et al (1999) reported that the reduced postural stability in persons with diabetic neuropathy cannot be attributed exclusively to loss of plantar cutaneous sensation; it appears to be the result of a general loss of peripheral sensory receptor function in the lower legs, including that of the muscle spindles. If the tibialis anterior muscle is affected by motor neuropathy, there would be rapid uncontrolled foot slap or foot drop during the initial period of gait, after the heel makes contact with the ground. This would reduce the capacity of the foot to absorb shock.

Walking is a highly integrated function that requires the coordinated contribution of multiple physiological subsystems (Ferrucci et al, 2000). On the other hand, diabetes is a chronic condition characterised by a progressive and simultaneous impairment of multiple organ subsystems that play a crucial role in walking physiology (Volpato et al, 2002). Cross-sectional and longitudinal analyses of the Health Ageing and Body Composition study have demonstrated that older diabetic individuals had lower muscle strength and muscle quality compared to their non-diabetic counterparts (Park et al, 2007).

The results of 6MWT could be due to numerous alterations, the main ones being inflammation, apoptosis, oxidative stress, abnormal glucose and lipid or oxidative enzyme metabolisms, abnormal microcirculation, or abnormal type of fibre. Persons with diabetic neuropathy have been found to walk slower, with shorter stride lengths and increased double support which can be interpreted as a safety strategy. While their walking pattern was more variable with respect to the movement pattern of the ankle joint, the overall stability was greater compared to the control subjects. These findings seem to support the notion that a slower gait is used to provide more safety for these individuals. A recent study from Brazil by Martinelli et al (2013) suggested that ankle muscle strength and joint mobility are the key factors influencing gait abnormalities in people with diabetic peripheral neuropathy. This is in agreement with findings in this study.

The results of this study are in accord with a similar study from Japan which found that a training programme designed to improve both sensory and motor function was effective in the improvement of balance among older adults (Tanaka et al, 1996). Standardised assessment of muscle characteristics and lower-extremity function, with early detection of sarcopenia and impaired muscle quality, might prompt appropriate lifestyle or medical interventions to postpone functional decline, prevent disability, and preserve independence and quality of life of older persons with diabetes. Therefore people suffering from peripheral neuropathy could benefit even more from a structured exercise regimen, as their condition provides greater scope for improvement.

CONCLUSION

The multisensory exercise training programme can improve the balance of diabetic people with peripheral neuropathy. However, there was no statistically significant difference in gait speed for those in the experimental group who were given multisensory exercise training. The improvement in multisensory re-weighting and the possible linkage of psychological well-being are the probable adjuvant mechanisms of balance improvement. Further, multisensory exercise is low-cost and can be practiced both indoors and outdoors.

Limitations and Recommendations

Further studies are needed which include larger heterogeneous samples, to explore the influence of these improvements on the number of reported falls and physical activity level of persons. Even though body weight, height and body mass index were taken into account, there was no attempt to measure quadriceps strength or leg length which could influence study results. Also, with regard to the issue of social disadvantage, the Quality Of Life (QOL) of the study participants should have been examined.

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