Journal of Bodywork & Movement Therapies (2015) 19, 453—457

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/jbmt

ORIGINAL RESEARCH

Long-term benefits of somatosensory training to improve balance of elderly with diabetes mellitus

Patrícia Silva, PhD [b], Priscila Fernanda Figueredo Borges Botelho, BSc [b], Elaine Caldeira de Oliveira Guirro, PhD [a], Maíta Mara O.L.L. Vaz, BSc [a], Daniela Cristina Carvalho de Abreu, PhD [a,*]

[a] *Physiotherapy Course, Department of Biomechanics, Medicine and Rehabilitation of Locomotor System, University of São Paulo, School of Medicine at Ribeirao Preto, FMRP/USP, SP, Brazil*
[b] *Center for Integrated Rehabilitation of the State Hospital of Ribeirão Preto (CIRHER), Ribeirão Preto, Brazil*

Received 4 August 2014; received in revised form 22 October 2014; accepted 3 November 2014

KEYWORDS
Postural control;
Physiotherapy;
Peripheral neuropath

Summary We evaluate the effects of somatosensory training on the mean amplitude of the center of pressure (COP) in the upright position and the sustained benefits after 6-month. Twelve elderly patients with type II diabetes (T2DM) participated in the study. Patients with T2DM were allocated to the somatosensory protocol, which consisted of a circuit composed of 13 stations with different textures. The rehabilitation protocol was applied twice a week during the period of 12 weeks. Upright balance, in 2 situations (fixed platform with eyes open and closed) to evaluate the mean amplitude of COP oscillation in the anterior-posterior and medial-lateral directions and the total area of COP oscillation. Outcomes were assessed at baseline, post-exercise and 6-month follow-up. The somatosensory training protocol was beneficial to reduce the AP oscillation of the COP, remaining after 6 months of the end of intervention in elderly with T2DM.

* Corresponding author. Avenida Bandeirantes, 3900, Ribeirão Preto, SP, CEP: 14049-900, Brazil. Tel.: +55 163602 4413/3058.
E-mail address: dabreu@fmrp.usp.br (D.C.C. de Abreu).

http://dx.doi.org/10.1016/j.jbmt.2014.11.002

Introduction

Type II diabetes mellitus (T2DM) is considered one of the most serious health problems, with great impact on the social and economic life of the country. In Brazil, due to the high incidence and prevalence, the disease is considered epidemic. Its prevalence increases markedly with age in all populations (Morrison et al., 2010; Santos et al., 2008; Silva et al., 2007) and it is predicted that approximately 11.3 million Brazilians will be diagnosed with diabetes by 2030 (Silva et al., 2007; Santos et al., 2008).

Diabetic neuropathy (DN) is the most common complication of DM (Gabliardi, 2003; Leonard et al., 2004) that causes a distal impairment in lower extremity sensory function, which may affect postural control (Gutierrez et al., 2001). Hyperglycemia is considered the main risk factor for the development of neuropathy (Boulton, 2005; Santos et al., 2008). An impaired insulin secretion has numerous primary and secondary effects on the body, including microvascular and macrovascular complications (Chudyk and Petrella, 2011). The neuropathic changes affect the autonomic and somatic nervous system. Consequently, the clinical complications of DN are extremely varied and could worsen the patient's quality of life.

Symptoms such as dizziness and unbalance are common in individuals with T2DM. In this condition, the neurological disorder usually begins at the tips of the toes or fingers and gradually spreads upward (Boulton, 2005). Its chronicity may damage the large sensory fibers causing reduced tactile sensitivity, in addition to a deficit in postural control. The damage to the small fibers produces decreased sensation of pain and temperature perception (Boulton, 2005; Gadsy, 2000).

Individuals with impairment in sensory function, mainly the sensitivity in the plantar region, have poor balance performances in static and dynamic tests (Dijs et al., 2000). Leonard et al. (2004) suggesting that when there is a reduction of sensory functions, there is also a decrease in the activities of the antigravity muscles.

A chronic sensory-motor change can interrupt the afferences and the efferences of the lower extremities, which are responsible for maintaining posture and normal gait (Cavanagh et al., 1992).

Morrison et al. (2010) presented evidence of postural changes as slower reaction time and increased postural sway in subjects with mild to moderate neuropathy. The authors reported that older individuals with DMT2 could present balance impairment and an increased risk of falls.

Reduced postural control is one of the major complications of DM. It is not only associated with a decline of the functions of the peripheral sensory system, but also with some specific clinical findings, such as reduced muscle strength, lower limbloading asymmetry, visual impairment, alteration of the vestibular system and loss of proprioception (Del Pozo Cruz et al., 2014; Cenci et al., 2013).

Therefore, any decline in balance control can be especially problematic since it is often a predictor of increased risk of falling in this population and has become a public health concern. Consequently, it is necessary to develop rehabilitation programs in an attempt to minimize the risk of falls and the comorbidities derived from this condition (Morrison et al., 2012).

The main purpose of this study was to evaluate the effects of somatosensory protocol training on the oscillation of the center of pressure (COP) in the upright position and the sustained benefits after 6-month follow-up.

Method

Twelve volunteers with T2DM were selected at the Endocrinology Outpatient Clinic, Clinical Hospital of School of Medicine at Ribeirão Preto, University of Sao Paulo, Brazil (FMRP-USP). Inclusion criteria were T2DM elderly individuals who were not practicing any regular physical training, were taking injectable diabetes drugs, following a proper diet and able to detect application at least of 10 g by the Semmes-Weistein monofilaments (SORRI®, Bauru/SP, Brazil) in the sole foot according to the criteria adopted by the American Diabetes Association (2008).

The institution's ethics committee (Clinical Hospital of Ribeirao Preto, protocol number 89/04) approved this research. All volunteers signed an informed consent form.

Exclusion criteria were the following: history of cardiovascular, rheumatologic, neurological or musculoskeletal diseases that could interfere with the activities of daily life; had previously used medication for the central nervous system; vestibulopathy; presence of lower limb lesions or fractures in the last six months.

Upright balance was assessed at baseline, post-exercise and 6-month follow-up using a force platform (EMG System of Brazil, São José dos Campos, SP, Brazil) (Santiago et al., 2013). Spatial variation was calculated with the manufacturer's software; the vertical component of the reaction force (Fz) and the moments of force about the x and y axes were used as measures. Signal acquisition was performed at a sampling rate of 100 Hz, with signals filtered at a low-pass band with a cut frequency of 10 Hz. The analyses were performed using the software provided by the manufacturer.

The balance evaluation was performed through COP analyses, which were obtained in bipodal position under two conditions: eyes open and eyes closed. Previously to the evaluation of balance, the individuals remained sitting and relaxing for 5 min. To perform the test, the individuals remained in an upright position, barefoot with their shoulders and feet aligned and the arms along side the body.

In this posture, the test was performed in two different situations: standing on the wooden fixed platform with eyes open (FPEO) for 30 s and with eyes closed (FPEC) for 30 s. During the upright balance test with eyes open, there was a fixed point at a distance of 150 cm from the subjects. Three attempts were made for each position and a mean value was obtained. The anterior-posterior (AP) and medial-lateral (ML) oscillations of the COP and the total area of the COP oscillation were evaluated.

Data were collected at the beginning of the study, 12 weeks and 6 month follow-up after intervention.

Intervention

The somatosensory training consisted of a 45-min session, twice a week, for 12 weeks, which were held at Center for

Integrated Rehabilitation of the State Hospital of Ribeirão Preto (CIRHER). The sessions were divided into three phases: warm-up and stretching (15 min), somatossensitive training (30 min) and cool down (15 min). Blood pressure and glycemic index were checked before and after the intervention.

For the somatosensory training, the exercises were organized in circuits, which included balance training, coordination, concentration and visual control of the movements and the repetitions with the purpose of creating mechanisms of neuroplasticity to improve the sensory system, according to what has been proposed by Santos et al. (2008).

A circuit was composed of 13 stations with different textures. The participant was instructed to remain for 2 min at each station, following the rhythm of slow-paced and fast-paced songs. Each station was represented by the following materials: 1st) 10 cm thick foam with high density; 2nd) wooden box containing beans; 3rd) 2 cm thick mat, with a density lower than the station foam; 4th) wooden box containing cotton; 5th) 2 cm thick mat; 6th) balance board to train mid-lateral balance; 7th) the participants sat down and grabbed a towel spread on the floor using their toes (foot strengthening exercise); 8th) 10 cm thick foam; 9) proprioceptive balls with 8 cm diameter and external projections placed on the floor for somatosensory stimuli in different regions of the foot; 10th) wooden box with millet; 11th) 2 cm thick mat; and 13th) sandpaper (abrasive mineral) to slide the feet for somatosensory stimuli. The cool down activities included breathing exercises, slow, free and active movements, stretching of the upper and lower extremities and the lumbar and sacral areas.

Statistical analysis

The Kolmogorov–Smirnov test was used to determine the consistence of the stabilographic data, followed by the analysis of variance (ANOVA) and the Tukey–Kramer Multiple Comparisons Test. The significance level was set at 5%.

Results

Demographic data included elderly with mean age of 70 ± 7.07 years, mean height of 1.62 ± 0.8 m and mean body mass of 68.3 ± 2.3 kg. The average time to diagnosis was 8.4 ± 3.5 years.

Eyes open

The results showed a significant decrease ($p < 0.001$) in the AP oscillation of the COP comparing the initial (2.17 ± 0.72 cm) and after 12 weeks (0.62 ± 0.42 cm). Significant difference was found ($p < 0.01$) between the initial and after 6-month follow-up (1.34 ± 0.68 cm). There were no significant difference between the AP oscillation after exercise and the 6-month follow-up ($p < 0.05$). For the ML oscillation of the COP (Fig. 1) with eyes open, there were no significant differences ($p > 0.05$) between the initial (2.23 ± 077 cm), after 12 weeks (1.50 ± 0.63 cm) and 6-month follow-up (1.98 ± 0.73 cm).

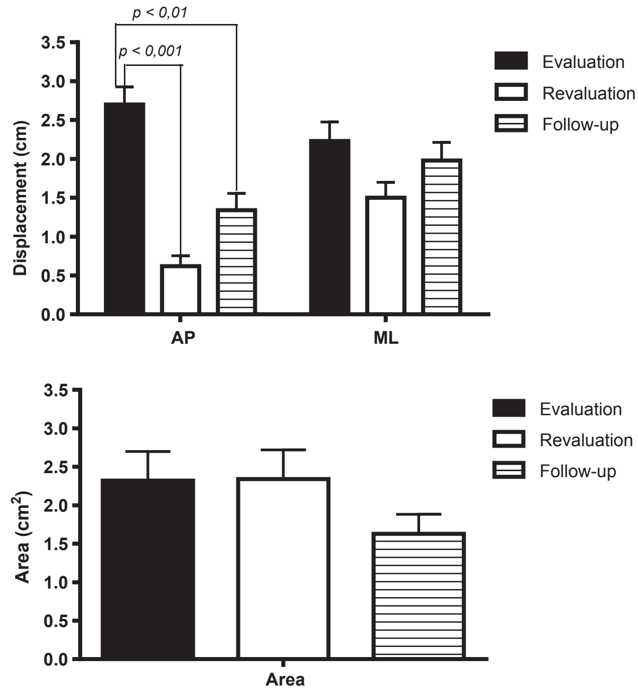

Figure 1 Mean values and SD of the AP and ML oscillation of the COP and the total area of COP with eyes open in three different moments. AP = anteroposterior, ML = mediolateral *$p < 0.05$.

For the total area of COP oscillation, with eyes open, no significant differences was observed ($p > 0.05$) between the initial (2.32 ± 1.2 cm) and after 12 weeks (2.34 ± 1.2 cm) and between the initial and 6-month follow-up (1.63 ± 0.8 cm) (Fig. 1).

Eyes closed

The results obtained with eyes closed showed significant differences ($p < 0.001$) in the anterior-posterior oscillation of the COP between the initial (2.47 ± 0.75 cm) and after 12 weeks (0.84 ± 0.61 cm).

The comparison between the initial and after 6-month follow-up (1.22 ± 0.79 cm) showed significant difference ($p < 0.01$). No significant difference was observed after the exercise protocol compared to 6-month follow-up ($p < 0.05$) (Fig. 2).

For the ML oscillation of the COP, no significant differences ($p > 0.05$) between the initial (1.84 ± 0.78 cm), after 12 weeks (1.47 ± 0.72 cm) and the 6 month follow-up were observed (1.66 ± 0.88 cm) (Fig. 2).

For the total are of COP oscillation, no significant differences were observed ($p > 0.05$) between the initial assessment (3.85 ± 2.2 cm^2) and after 12 weeks (3.77 ± 3.2 cm^2) and between the initial and the 6-month follow-up (1.87 ± 0.8 cm^2) (Fig. 2).

Discussion

Older adults with T2DM are more likely to fall and have diabetes-related complications. Factors of particular concern include peripheral neuropathy, reduced vision, use

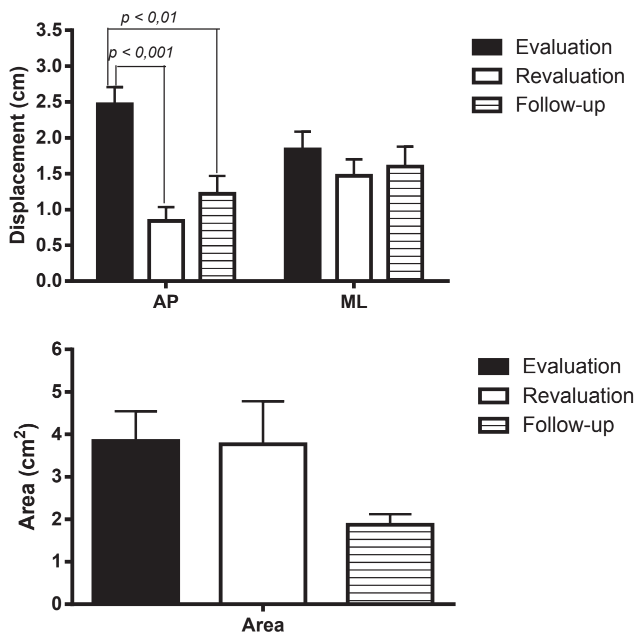

Figure 2 Mean values and SD of the AP and ML oscillation of the COP and the total area of COP oscillation with eyes closed in three different moments. AP = anteroposterior, ML = mediolateral $*p < 0.05$.

of medication, dizziness, hearing impairment and hypoglycemic episodes (Schwartz et al., 2008).

All volunteers present minimum sole foot sensitivity 10 g (force) tested by the Semmes-Weinstein monofilament, with loss of protective sensation in the feet, but could still feel deep pressure and pain. The reduction of the plantar tactile sensitivity was more evident in the sole than in the dorsum of the foot, which justified the plantar somatosensory training protocol. McGill et al. (2001) and Santos et al. (2008) showed that the 10-g monofilament has sensitivity and specifity rates of 88 and 69%, respectively, for the assessment of the plantar tactile sensitivity.

The upright balance of diabetic individuals was evaluated with and without visual information, before, immediately after a 12-week somatosensory intervention program and after six months following the exercises to observe the sustained benefits.

Although the clinical condition associated with DM is widely known, Gomes et al. (2007) confirmed the scarcity of scientific studies on the physiotherapeutic treatment for patients with diabetes mellitus, which justifies the need for further research aimed to develop rehabilitation programs to improve functionality and balance in this population.

Gomes et al. (2007) have developed and applied a physiotherapeutic treatment for diabetic neuropathy based on stretching the posterior chain and anterior tibial, resistance training for intrinsic muscles of the foot and ankle; training of daily life activities and self-care guidelines for the feet, and obtained positive results. The authors observed that the proposed treatment was effective in alleviating symptoms of numbness, tingling and burning sensation due to the better neural conduction promoted by kinesiotherapy.

Dijs et al. (2000) treated diabetic patients with limited joint mobility using physiotherapy methods. This treatment resulted in improved joint mobility, and consequently, the load distribution in the areas of the feet during gait and reduced high pressure, which may prevent ulceration. However, the authors emphasized that the use of physiotherapy may only result in temporary improvement.

The proprioceptive training protocol selected for this study was based on the positive results obtained by Santos et al. (2008) that showed improved plantar tactile sensitivity and reduction of AP oscillation in the elderly population after training. The authors found an association between greater AP oscillation amplitude with the proprioceptive impairment found in individuals affected by DM, which was also observed in this study, leading to the conclusion that the therapeutic intervention resulted in multisensory stimulation, improving the postural stability in the studied population.

The studies of Meyer et al. (2004) and Sales et al. (2012) reported that the changes in surface plantar sensitivity has negative effects on the control of upright balance. Also, Mettelinge et al. (2013) report the negative influence of peripheral neuropathy on gait of the elderly with T2DM, leading to greater risk of falling. Stegemoller et al. (2012) emphasize that this altered gait behavior could be a compensatory strategy to bring the COP back inside the support base and to increase dynamic stability.

The results of the present study showed a reduction of the anterior-posterior oscillations of the COP with open and closed eyes in the elderly with T2DM after 12 weeks of intervention. The improvement of postural instability may be related with the lowest latency time postural observed in the reestablishment of the balance promoted by the proprioceptive training. The COP oscillation amplitude remained low even after 6 months post intervention.

The base of support in the upright position used in the present study (bipodal position) may have contributed to the absent of reduction of the ML oscillation of the COP after intervention, since the tandem position of the feet probably is more appropriate for evaluating the ML oscillation.

Clinically, one of the significant findings of the present study was the maintenance of AP body sway followed 6 months of the somatosensory training protocol, showing that despite T2DM being a chronic illness, the intervention was effective in reducing the oscillation of the COP. Based on the statement that appropriate postural control is achieved when body sway is kept to a minimum, the decrease of AP oscillation observed in the present study can contribute to reduce the risk of falling in this population (Strang, 2011).

These results corroborate those of Sales et al. (2012) who have applied the same proprioceptive training and observed improvement in plantar tactile sensitivity after six months of intervention. However, that study focused on evaluation immediately after the intervention. In our study, we observed improvement of plantar tactile sensitivity after a short period of time (12 weeks), which was maintained after 6 months of follow up.

The limitations of the study include the small sample size, since the elderly patients had low adherence in the rehabilitation.

Conclusion

The somatosensory training reduced the mean amplitude of the AP oscillation with sustained benefits after 6-month follow up in elderly individuals with T2DM.

Ethics in publishing

The institution's ethics committee (Clinical Hospital of Ribeirao Preto, protocol number 89/04) approved this research. All volunteers signed an informed consent form.

References

American Diabetes Association, 2008. Standards of medical care in diabetes. Diabetes Care 31 (Supple 1), S12—S54.
Boulton, A.J.M., 2005. Management of diabetic peripheral neuropathy. Clin. Diabetes 23, 9—15.
Cavanagh, P.R., Hewitt, F.G., Perry, J.E., 1992. In shoe plantar pressure measurement: a review. Foot 12, 185—194.
Cenci, D.R., Silva, M.D., Gomes, E.B., Pinheiro, H.Á., 2013. Análise do equilíbrio em pacientes diabéticos por meio do sistema F-Scan e da Escala de Equilíbrio de Berg. Fisioter. Mov. 26, 55—61.
Chudyk, A., Petrella, R.J., 2011. Effects of exercise on cardiovascular risk factors in type 2 diabetes. Diabetes Care 34, 1228—1237.
Del Pozo-Cruz, B., Afonso-Rosa, R.M., Del Pozo-Cruz, J., Sanudo, B., Rogers, M.E., 2014. Effects of a 12-wk whole-body vibration based intervention to improve type 2 diabetes. Maturitas 77, 52—58.
Dijs, H.M., Roofthooft, J.M., Driessens, M.F., De Bock, P.G., Jacobs, C., Van Arcker, K.L., 2000. Effect of physical therapy on limited joint mobility in the diabetic foot: a pilot study. J. Am. Podiatr. Med. Assoc. 90 (3), 126—132.
Gabliardi, A.R.T., 2003. Neuropatia diabética periférica. J. Vasc. Bras. 2, 67—74.
Gadsy, R., 2000. The diabetic foot in primary care: a UK perspective. In: Boulton, A.J.M., Connor, H., Cavanagh, P.R. (Eds.). Wiley John and Sons Ltd, pp. 95—103.
Gomes, A.A., Sartor, C.D., João, S.M.A., Sacco, I.C.N., Bernik, M.M.S., 2007. Efeitos da intervenção fisioterapêutica nas respostas sensoriais e funcionais de diab[éticos neuropatas. Fisioter. pesqui. 14 (1), 14—21.
Gutierrez, E.M., Helber, M.D., Dealva, D., Miller, J.A.A., Richardson, J.M., 2001. Mild diabetic neuropathy affects motor function. Clin. Biomech. 16, 522—528.
Leonard, D.R., Farooqui, H., Myers, F., Myers, S., 2004. Restoration of sensation, reduced pain, and improved balance in subjects with diabetic peripheral neuropathy. Diabetes Care 27, 168—172.
McGill, M., Molyneaux, L., Spencer, R., Heng, L.F., Yue, D.K., 2001. Possible sources of discrepancies in the use of the Semmes-Weinstein monofilament. Impact on prevalence of insensate foot and workload requirements. Diabetes Care 24 (1), 183—194.
Mettelinge, T.R., Delbaere, K., Calders, P., Gysel, T., Noortgate, N.V., Cambier, D., 2013. The impact of peripheral neuropathy and cognitive decrements on gait in older adults with type 2. Diabetes Mellit. 94, 1074—1079.
Meyer, P.F., Oddsson, L.I.E., De Luca, C.C.C.J., 2004. The role of plantar cutaneous sensation in unperturbed stance. Exp. Brain Res. 156 (4), 505—512.
Morrison, S., Colberg, S.R., Mariano, M., Parson, H.K., Vinik, A.I., 2010. Balance training reduces falls risk in older individuals with type 2 diabetes. Diabetes Care 33, 748—750.
Morrison, S., Colberg, S.R., Parson, H.K., Vinik, A.I., 2012. Relation between risk of falling and postural sway complexity in diabetes. Gait Posture 35, 662—668.
Sales, K.L.S., Souza, L.A.C., Vinicius, S., 2012. Equilíbrio estático de indivíduos com neuropatia periférica diabética. Fisioter. Pesqui. 19 (2), 122—127.
Santiago, H.A.R., Reis, J.G., Gomes, M.M., Herrero, C.F.P.S., Defino, H.L.A., Abreu, D.C.C., 2013. The influence of vision and support base on balance during quiet standing in patients with adolescent idiopathic scoliosis before and after posterior spinal fusion. Spine J. 13, 1470—1476.
Santos, A.A., Bertato, F.T., Montebelo, M.I.L., Guirro, E.C.O., 2008. Effect of proprioceptive training among diabetic women. Rev. Bras. Fisioter. 12, 183—187.
Schwartz, A.V., Vittinghoff, E., Sellmeyer, D.E., Feingold, K.R., Rekeneire, N., Strotmeyer, E.S., 2008. Diabetes-related complications, glycemic control, and falls in older adults. Diabetes Care 31 (3), 391—396.
Silva, R.C.P., Simões, M.J.S., Leite, A.A., 2007. Fatores de risco para doenças cardiovasculares em idosos com diabetes Mellitus tipo 2. Rev. Ciênc Farm Básica 28, 113—121.
Stegemoller, E.L., Buckley, T.A., Pitsikoulis, C., Barthelemy, E., Roemmich, R., Hass, C.J., 2012. Postural instability and gait impairment during obstacle crossing in Parkinson's disease. Arch. Phys. Med. Rehabil. 93, 703—709.
Strang, A.J., 2011. Structural changes in postural sway lend insight into effects of balance training, vision, and support surface on postural control in a healthy population. Eur. J. Appl. Physiol. 111 (7), 1485—1495.