EFFECTS OF BALANCE EXERCISE AND SOMATOSENSORY STIMULATION ON SOMATOSENSORY RESPONSE IN DIABETIC PERIPHERAL NEUROPATHY

Zahra Sativani, Bambang Purwanto, Dwikora Novembri Utomo
Sport Science, Department of Physiology, Universitas Airlangga
zsativani@gmail.com; bpaifo@gmail.com; dwikora_utomo@yahoo.com

Abstract

Somatosensory dysfunction has become the main problem in diabetic peripheral neuropathy. Balance exercise and somatosensory stimulation are exercises to improve balance and somatosensory responses. However, there is no available sufficient evidence measuring the somatosensory response after practicing balance exercise and somatosensory stimulation. This research aims to investigate the effects of balance exercise and somatosensory stimulation on somatosensory response in diabetic peripheral neuropathy. This was experimental research, 12 type II diabetes with onset > 10 years were enrolled, randomized, and divided into two groups. For three weeks, group 1, an intervention group (N = 6) practiced balance exercise and somatosensory stimulation for five days a week. Group 2, a control group (N = 6) received education for two times in three weeks. The end of the period, the intervention group showed a significant improvement in neuropathy scores (p=0.013). Balance exercise and somatosensory stimulation could improve somatosensory response in diabetic peripheral neuropathy.

Keywords: type 2 diabetes, diabetic neuropathy, static balance, dynamic balance, somatosensory stimulation**.**

Introduction

Type II diabetes mellitus is one of the fastest growing health problems in the world. The International Diabetes Federation (IDF) said that in 2012, there were 280 million people in the world suffered from impaired glucose tolerance (IGT) and it was projected to reach 400 million people by 2030. In 2013, in Indonesia, the proportion of impaired glucose tolerance IGT) reached 29.9% or 52 million people and impaired fasting glucose (IFG) reached 36.6% or 64 million people (Ministry of Health of the Republic of Indonesia 2014; World Health Organization 2016).

Hyperglycemia as a result of IFG and IGT is one of the causes of neurological disorders, which is somatosensory dysfunction. Somatosensory dysfunction in the lower limb can trigger the decrease in ankle position/proprioception and vibration senses. In addition, somatosensory dysfunction can cause postural instability that leads to the increase in fall risks (Gu & Dennis 2016; Rojhani-Shirazi, et al., 2016). IFG and IGT are intermediate status of pre-diabetes (type II) relating to the increase in risk of macro and microvascular complication (Bilous & Donelly, 2014). Hyperglycemia causes somatosensory dysfunction through the mechanism of peripheral nerve damage. Peripheral nerve damage includes sensory nervous system disorders, especially somatosensory, motor, and autonomic receptors (Gow & Moore, 2014; Taveggia, G. et al., 2013).

Diabetic peripheral neuropathy is a microvascular complication that affects 50% of people with diabetes mellitus (Juster-Switlyk & Smith 2016). The number of peripheral neuropathy cases in 2011 at RSCM was 54%. Diabetic peripheral neuropathy causes the decrease in neuromuscular response that may increase the fall risks. Neuropathy causes changes in the nervous system due to chronic hyperglycemia. The longer the individual suffered from hyperglycemia, the risk of complications is getting higher (Allen et al., 2014; Morrison et al., 2010; Taveggia, G. et al., 2013). Some studies say that patients suffered from type II DM with onset of hyperglycemia > 10 years, experience decreased in impulse delivery speed and axon damage. Somatosensory dysfunction may increase the risk of injury due to reduced sensation, leading to increase in fall risk, ulceration, and amputation (Al-Rubeaan et al., 2015; Dunnigan et al., 2013).

The efforts in preventing fall risk is by increasing somatosensory and balance responses. Kutty & Majid's research (2013) states that there is a change in timed up and go test (TUG), in contrast there is no change in the result of six minutes walking test (6MWT) after multisensory training had been done. El-wishy & Elsayed (2012) research states that there is an increase in berg balance score (BBS) after proprioceptive training had been done. The presence of somatosensory input is an important factor for maintaining somatosensory and postural stability responses. However, until now, there is no research that has been found to prove a change in somatosensory response, if it is seen from the score of neuropathy in diabetic peripheral neuropathy. This research aims to examine the effects of balance exercise and somatosensory stimulation on somatosensory responses in diabetic peripheral neuropathy.

Research Method

Research design and subject

This was a field experimental research. It was performed at *Rumah Diabetes Universitas Surabaya.* This research used a pre-posttest with control group design involving 12 people, aged 50-65 years; eight females and four males. They have been injected by insulin and clinically diagnosed with type II diabetes for > 10 years. They were able to walk without using aided tools (namely, tripod, walker, etc.) and willing to involve in the research. There were exclusion criteria including having history of fractures, vestibular disorders, visual impairments that could not be corrected using eye glasses, open sores or foot ulcers on the feet. Assessment was conducted by assessing neuropathy score before and after treatment. Assessment of neuropathy scores performed by using neuropathy check sheets for diabetic protocol Rosyida (2016) was the result of combination of two instruments frequently used as clinical parameters of early detection of neuropathy and assessment of neuropathy degrees that was the Michigan Neuropathy Screening Instrument (MNSI) and the Michigan Diabetic Neuropathy Score (MDNS). Assessment consisted of examination of autonomic, sensory, and motor functions. Examination was performed using 10-gram monofilament, 128 Hz tuning fork, reflex hammer, and pin prick. The total score indicated the range of neuropathy categories. The neuropathy examination sheet for diabetic protocol Rosyida (2016) had the instrument validity of 0.361-0.765 (r table 0.361) and reliability is 0.703 (r count> 0.60).

After the sample size was met, randomization was performed to determine the intervention and control group. The groups were determined using random allocation technique. The intervention group (N = 6) received balance exercise and somatosensory stimulation five times a week for three weeks. The control group (N = 6) received education twice in three weeks. This research has passed the ethics at the Faculty of Dentistry, Universitas Airlangga (056 / HRECC.FODM / V / 2017).

Procedure and Intervention

Balance exercise and somatosensory stimulation were performed five times a week for three weeks. One practice session was conducted for 55 minutes (5 minutes for heating, 45 minutes for core training, and 5 minutes for cooling) (Fall Prevention Center of Excellence, 2010; Rojhani-Shirazi, et al., 2016). Assessment was performed before and after the training had been conducted for three weeks.

The balance exercise using protocol training ball method Rojhani-Shirazi (2016) was combined with the movement from the Fall Prevention Center of Excellence at California State University. The exercises were practiced in groups and in two positions, that were sitting (in the chair and swiss ball) and standing, and it was grounded with synthetic grass as somatosensory stimulation media. 1-Exercise in the sitting position, patient with diabetes had to sit upright and move their ankle in opening and closing direction, lift the forefoot but maintain the heel to be attached, lift the leg at the same time to be in line with the thigh, sit upright and hold the ball with both hands then move the hands over and above the head, rotate the body to the left and right, cross the body bent from the top right side to the lower left side (do the opposite), sit and pass the ball with the hands and feet. 2-Exercises in standing positions, patient with diabetes had to exercise tandem standing and walking, semi-tandem standing and walking¸ pass the ball with both hands while walking, pass the ball with both hands from over the head and from the bottom between the legs, pass the ball with the legs.

The control group received education about diabetes and diabetes neuropathy, foot care and exercise that could be done at home. Education was given twice in three weeks.

Statistical Analysis

Statistical analysis was performed using SPSS version 16.0. The descriptive analysis test calculated mean and standard deviation scores. Then it was continued with normality test using Shapiro-wilk. Mean difference analysis was performed through paired sample t test and independent sample t test. Paired sample t tests were performed to determine pre and posttest changes in each group. The p value <0.05 indicates a significant change.

Finding and Discussion

Finding

Descriptive analysis of the subject characteristics described that there was no significant difference between the two groups in the variables of age, weight, height, BMI, RBS, and duration to have diabetes. Based on the Shapiro-wilk normality test, the descriptive data of subject characteristics was normally distributed (p> 0.05). Neuropathic scores in both groups showed normal distributed data. The data are presented in Table 1.

Mean difference analysis using paired sample t-test showed significant difference before and after the balance exercise and somatosensory stimulation (p<0.05) in the intervention group (p=0.002). In contrast, the control group did not show any significant differences (p=0.341). Data are presented in Table 2.

Mean difference analysis using independent sample t-test showed that there were significant differences after balance exercise and somatosensory had been implemented in intervention and control group and it was shown by post-pre neuropathy score difference in each group (Delta Neuropathy). Data are presented in Table 3.

Discussion

Table 1 explains that patients with type II DM, with an average age of 56-60 years and with a prolonged average to have diabetes of 24 years have early symptoms of neuropathic complications. Parisi et al. (2016) research states that the prevalence of patients with diabetic peripheral neuropathy is mostly found in patients with average age of age 50-59 years. It is the same with the research by Dunnigan et al. (2013) stating that the risk of diabetic foot state occurs at age 45-64 years with the number of cases of 845 (40.80%). More than 50% of old patients with diabetes with long-term diabetes > 25 years have neuropathy with the disturbance in the peripheral nervous system (distal) in the lower extremities and sensory system disturbances contributing in to postural control settings, such as somatosensory system (Kutty & Majid, 2013). Sharma et al. (2011) research states that the prevalence of DM increases with age. Patients with diabetes have fall risk 15 times higher than non-diabetics in the same age.

Table 1

Mean, standard deviation, normality test of research subject characteristics.

Variable	Mean ±SD Intervention group (N=6)	Mean ±SD Control Group (N=6)	p
Age (years old)	60.17±4.07	56.83±5.74	0.163
Weight (kg)	58.58±4.24	59.50±8.61	0.160
Height (cm)	152.75±6.91	158.42±9.56	0.824
BMI (kg/m^2)	25.06±2.07	23.64±1.90	0.287
RBS (mg/dl)	189.83±58.55	202.67±69.67	0.413
Duration having diabetes (year)	24.67±5.12	24.17±7.16	0.089
Pre Neuropathy score	8.50±3.67	8.00±4.29	0.215

SD=Standard Deviation; BMI=Body Mass Index; RBS=Random Blood Sugar; N=number of subject per group

Table 2

Analysis of difference before and after intervention in experimental and control group using paired sample t-test

Group	Mean ±SD *Pre test*	Mean ±SD *Post test*	P
Intervention	8.50±3.67	4.50±2.42	0.002*
Control	8.00±4.29	7.17±4.16	0.341

*Significant value p<0.05

Table 3

Analysis of difference before and after intervention in experimental and control group using independent sample t-test

Group	Mean±SD Intervention	Mean±SD Control	p
Neuropathy Score Delta	-4.0±1.67	-0.83±1.94	0.013*

Description: Neuropathy Score Delta = neuropathy score difference before and after intervention in each group. *Significance value p<0,05

While standing and walking, somatosensory input is required as feedback to recognize the body's position on the environment as well as plan and coordinate movement to be balanced at various positions. The use of somatosensory information in a flat environment was 70% (Qiu, 2012). This shows that somatosensory provides the greatest response in maintaining balance. Individuals experiencing the decrease in somatosensory information will be unable to deliver information to the central nervous system, therefore, the risk of impairment is getting higher (Sharma et al., 2011).

Balance is a complex integration between somatosensory (visual, vestibular, proprioception) and motor systems that are regulated by the central nervous system. Loss of somatosensory responses, especially cutaneous plantar sensations, is a major cause of movement disturbances for diabetic neuropathy while they are standing and walking (Lowrey, 2012; Kafa, 2015). In patient with diabetic neuropathy, peripheral nerve damage may occur as a result of the body systemic process affecting nerve fibers that play a role in the touch and movement senses. Peripheral nerve damage is also associated with decrease in impulse velocity of unit motor and axon motors, thus it may increase the risk of injury and falling incidence (Allen et al., 2014; Al-Rubeaan et al., 2015).

The decrease in impulse delivery rate is found to rarely occurs in patients with type II DM, with mean diabetes duration of 15.2 ± 10.6 years, whereas axon damage occurs in the mean of long-term diabetes of 14.9 ± 7.9 years (Dunnigan et al., 2013). The decrease in impulse delivery rate and axon damage is caused by abnormalities of neuron in Schwann cells, myelin membranes, and axons. This causes patients with type II DM feel the early symptoms of neuropathy that is neuropathic pain and distal parasthesiae. If the damage occurs in a long term, then the axons of nerve cells will disappear. In addition, according to Souza et al. (2015), age affects the prevalence of neuropathy diabetes relating to the presence of degenerative factor that is decrease in body function especially the ability of pancreatic β cells in producing insulin.

In addition to age, blood glucose level plays a role in the increased in risk of diabetic neuropathy. The higher the blood glucose level, the greater the risk of neuropathy is. The high blood glucose level causes the blood flow to decrease so that the risk of peripheral nerve damage in the leg increases and then it is followed by the lack of foot sensitivity (Parisi et al., 2016).

Balance exercise and somatosensory stimulation was practiced in the experimental group. Balancing exercise used Swiss ball (ball training) and somatosensory stimulation was conducted by using artificial grass mats. Ball training is a method of balance exercise that trains the abdominal muscles/core work and postural control. Core work and postural control is one of factors affecting base of support and they are involved in determining the position of center of gravity. The center of gravity plays a role in distributing the mass of objects evenly and maintaining the body in balance (Raju, 2012; Kafa, 2015).

Balance exercise improves the balance control through postural stability. Postural stability is an interaction among visual system, vestibular, and sensory. The changing presented in one of those systems, namely sensory deficit in feet, can cause postural instability. Postural instability on patients with diabetic neuropathy is not a direct impact of the loss of plantar cutaneous sense, but it is caused by the loss of all sensory receptor functions in both legs, including muscle spindle function.

The provision of synthetic grass mats is intended to stimulate cutaneous and subcutaneous receptors. Somatosensory input that derives from the feet due to the different exercise surface stimulates cutaneous receptors relating to deep sensation. Deep sensation is caused by the presence of receptors in the joints and muscles (subcutaneous / proprioceptor). Both joint and muscle interact to form a motion-related information such as sensations of position and velocity and touch. Each somatosensory input that is received is involved in forming postural control. Provision of continuous exercise will stimulate muscle spindle receptors. Muscle spindle is a major component of proprioceptive development in the ankle joint which will provide input to the cerebellum as the center of the balance of the body. Somatosensory stimulation plays a role in increasing the sensitivity of the sensory receptors in the legs because with the increase in sensory input quality, the postural control will be formed so body sway will decrease and the body will be more standby when there is a change in balance. (Gu & Dennis, 2016; Kafa, 2015).

There is a significant change on neuropathy score in this research after balance exercise and somatosensory stimulation had been conducted five times a week for three weeks. Alfieri et al. (2010) states that there is a significant change in balance control and dynamic activity after multi-sensory exercise had been conducted to the elderly with impaired functional mobility and balance. El-wishy & El-sayed (2012) in more detail explains that by following proprioceptive training twice a week for eight weeks may lead to a significant change in the mean of Berg Balance Score (BBS) from 1.286 to 5.786. Similarly, in the Kutty & Majid research (2013) states that there is a significant change in timed and up go test (TUG) from 13.3 ± 0.9 seconds to 11.2 ± 1.1

seconds. Systematic review research by Gu & Dennis (2016) describes 10 research of exercise for diabetic neuropathy, for example lower limb strengthening, balance practice, aerobic exercise, walking programs, and Tai Chi. Therefore, the diabetic neuropathy is able to improve static and dynamic balance. However, until now, there is no research that has been found to discuss the effects of balance exercise on somatosensory responses assessed from a neuropathy score.

Conclusions and Suggestions Conclusions

Impaired balance becomes a major disability in diabetic neuropathy. Impaired balance is caused by somatosensory dysfunction. Somatosensory input provides the greatest response in maintaining balance. Balance exercise and somatosensory stimulation can increase the somatosensory response; it is found from the increase in neuropathic scores. In addition, balance exercise and somatosensory stimulation can be taken indoors or outdoors and it can be used as home programs for every diabetic neuropathy.

Suggestions

It is necessary to perform further research with larger numbers of subjects to find the effects of balance exercise and somatosensory stimulation exercises on falling prevalence and physical activity abilities of diabetic neuropathy. It is also necessary to conduct follow up for several months after the exercise and stimulation had been performed to find the effect of exercise term. In addition, muscle strength examination can also be considered as one of the pre and post examinations.

Acknowledgment

The researchers would like to thank the CEO of *Rumah Diabetes Universitas Surabaya* Lisa Aditama, S.Si., M.Farm-Klin, Apt., Dewi Delia, S.Si., all the subjects, and all parties involved in this research.

References

Allen, M. D. Kurt, K. Timothy, J. D. Charles, L. R. 2014. Clinical Neurophysiology Length Dependent Loss of Motor Axons and Altered Motor Unit Properties in Human Diabetic Polyneuropathy. *Clinical Neurophysiology*. 125(4): 836-43. http://dx.doi.org/10.1016/j/clinph.2013.09.037.

Alfieri, F. M. Riberto, M. Gatz, L. S. Ribeiro, C. P. S. Lopes, J. F. Battistella,L. R. 2010. Functional Mobility and Balance in Community-Dwelling Elderly Submitted to Multisensory Versus Strength Exercises. *Clinical Interventions in Ageing*. 5: 181-185. http://dx.doi.org//10.2147/CIA.S10223.

Al-Rubbean, K. Al-Derwish, M. Ouizi, S. Youssef, A. M. Subhani, S. N. Ibrahim, H. M. Alamri, B. N. 2015. Diabetic Foot Complications and Their Risk Factors from a Large Retrospective Cohort Study. *PLos ONE*. 10(5):1-17. http://dx.doi.org/10.1371/journal.pone.0124446.

Billous, R. Donelly, R. 2014. Handbook of Diabetes 4th Edition. (Barrarah, Ed.). Buku Pegangan Diabetes Edisi Ke-4. Bumi Medika. Jakarta.

Dunnigan, S. K. Ebadi, H. Breiner, A. Katzberg, H. D. Lovblom, L. E. Perkins, B. A. Bril, V. 2013. Conduction Slowing in Diabetic Sensorimotor Polyneuropathy. *Diabetes Care*. 36(11): 3684-90. http://dx.doi.org/10.2337/dc13-0746.

El-wishy, A. A. Elsayed, E. 2012. Effect of Propioceptive Training Program on Balance in Patients with Diabetic Neuropathy: A controlled Randomized. *Bull. Fac. Ph. Th.Cairo Univ.* 17: 1-8. http://www.researchgate.net/publication/234129906.

Fall Prevention Center of Excellence. 2010. Balance and Mobility Exercises for Physical Classes. California State of University.

Gow, D. Moore, P. 2014. Assessing Diabetic Peripheral Neuropathy in Primary Care. *Best Practice Journal*. (61): 36-47. http://www.bpac.org.nz/BPJ/2014/june/docs/BPJ61-diabetic-peripheral-neuropathy.pdf.

Gu, Y. Dennis, S. M. 2016. Are Falls Prevention Programs Effective at Reducing the Risk Factors for Falls in People with Type-2 Diabetes Mellitus and Peripheral Neuropathy: A Systematic Review with Narrative Syntehesis Medline (OVID). *Journal of Diabetes and its Complications.* http://dx.doi.org/10.1016/j.jdiacomp.2016.10.004.

Juster-Switlyk, K. Smith, A. G. 2016. Updates in Diabetic Peripheral Neuropathy. *F1000 Research*. http://dx.doi.org/10.12688/f1000research.7898.1.

Kafa, N. 2015. *Foot Sensation, Balance, and Propioception*. OMICS Group eBooks. USA.

Kementerian Kesehatan RI. 2014. Waspada Diabetes: Eat Well, Life Well. *Pusat Data dan Informasi Kementerian Kesehatan RI*.

Kutty, N. Majid, N. 2013. Effects of Multisensory Training on Balance and Gait in Persons with Type 2 Diabetes: A Randomized Controlled Trial. *Disabbility CBR & Inclusive Development*. 24(2): 79-91. http://dx.doi.org/10.5463/DCID.v24i2.206.

Lowrey, C. 2012. Investigation of the Role of Skin and Muscle Receptors in Propioception at the Ankle Joint in Human. *Human Health and Nutritional Sciences Guelph.* Canada.

Morrison, S. Colberg, S. R. Mariano, M. Parson, H. K. Vinik, A. I. 2010. Balance Training Reduces Falls Risk in Older Individual with Type 2 Diabetes. *Diabetes Care*. 33(4): 748-50. http://dx.doi.org/10.2337/dc09-1699.

Parisi, M. C. *et al.* 2016. Baseline Characteristic and Risk Factors for Ulcer Amputation and Severe Neuropathy in Diabetic Foot at Risk: The BRAZUPA Study. *Diabetology & Metabolic Syndrome*. 8: 25. http://dx.doi.org/10.1186/s13098-016-0126-8.

Qiu, F. 2012. Effects of Enhanced Somatosensory Information on Postural Stability in Older People and People with Parkinson's Disease. *Thesis*. Movement and Neuroscience Program Queensland University.

Raju, Y. 2012. Maintenance of Balance and Rehabilitation in the Elderly. *Medicine Update Journal* Vol. 22.

Rojhani-Shirazi, Z. Barzintaj, F. Salimifard, M. R. 2016. Comparison the Effects of Two Types of Therapeutic Exercises Frenkele vs. Swiss Ball on the Clinical Balance Measures in Patients with Type II Diabetic Neuropathy. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*. 8-11. http://linkinghub.elsevier.com/retrieve/pii/S187140211631746.

Rosyida, K. 2016. Gambaran Neuropati Perifer Pada Diabetisi di Wilayah Kerja Puskesmas Kedungmundu Semarang. *Skripsi*. Universitas Diponegoro.

Sharma, V. Aggarwal, S. Sharma, A. 2011. Diabetes in Elderly. *Journal of Endocrinology and Metabolism*.1(1): 9-13. http://dx.doi.org/10.4021/jem11e.

Souza, R. J. D. Souza, A. D. Nagvekar, M. D. 2015. Nerve Conduction Studies in DiabeticsPresymptomaticand Sympromatic for Diabetic Polyneuropathy. *Journal of Diabetes and Its Complications*. 29(6): 811-17. http://dx.doi.org/10.1016/j.jdiacomp.2015.05.009.

Taveggia, G. Villafane, J. H. Vavassori, F. 2013. Multimodal Treatment of Distal Sensorimotor Polyneuropathy in Diabetis Patients: A Randomized Clinical Trial. *Journal of Manipulative and Physiological Therapeutics.* 37(4): 242-52. http://dx.doi.org/10.1016/j/jmpt.2013.09.007.

World Health Organization. 2016. Global Report on Diabetes. http://www.who.int.about/licensing\nhttp://apps.who.int/iris/bitstream/10665/204871/1/978924156527_eng.pdf.