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Review

Balance training in the intervention of fall risk in elderly with diabetic peripheral neuropathy: A review

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ABSTRACT

Diabetic peripheral neuropathy (DPN) was the most common complications of elderly diabetic, which could contribute to an increased risk of falling. Despite the increased prevalence of elderly diabetic, high risk of falls and serious consequences of falls in elderly with DPN, It is necessary to adopt means of reducing the risk of falls in elderly with DPN. Impaired balance in the elderly with DPN was the most important risk factor of increasing falls. This review will introduce the epidemiology of falls in elderly with DPN, analysis the reasons for high risk of falls in elderly with DPN, provide a review of the development of balance training in the intervention of fall risk in elderly with DPN and offer recommendations to medical personnels on how to provide an efficient balance training for elderly with DPN.

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1. Introduction

With the intensification of the degree of aging, the proportion of older people aged over 60 increased year by year [1], leading to an increased prevalence of diabetes in elderly [2]. Diabetic peripheral neuropathy (DPN) was the most common complications of elderly diabetic, occurring in up to 60% of elderly diabetic [3–5], leading to the decreased sensitivity of proprioceptive and vestibular function, slower reaction times, greater postural instability and altered walking patterns, which could contribute to an increased risk of falling [6]. It had

been shown that elderly who suffer a fall would have high incidence of fall-related fractures [7], delayed falls injury rehabilitation [8], and increased recurrent falls [9], thus resulting in reduced quality of life, and even increased mortality [10]. It had been noted that that impaired balance in the elderly with DPN was the most important risk factor of increasing falls [11]. Appropriate balance training could improve balance in elderly patients with DPN, and reducing its risk of falling. Currently, Balance training had been increasingly used in the risk of falls in elderly with DPN. This article reviews the research progress of application of balance training to fall risk in elderly with DPN.

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2. Epidemiology of falls in elderly with DPN

In recent years, Epidemiological studies showed a higher incidence of falls in the elderly with DPN. DeMott et al. [12] followed up 20 cases of elderly patients with DPN for 1 year and found that the incidence of falls of up to 65%. Similarly, In China, Xie Jinmei et al. [13] investigated 62 cases of elderly patients with DPN incidence of falls and found that 79% had occurred fall. Among people age 65 years and older, Falls were the most common cause of death [14]. Particularly, DPN would further increase their risk of falling, recent studies had shown that DPN was an independent risk factor for falls and injuries. Elderly with DPN were 23 times more likely to fall and are 15 times more likely to report an injury compared with matched non-neuropathic subjects [11]. So taking active intervention to reduce the risk of falls in elderly with DPN, to prevent falls in elderly with DPN, and to improve their quality of life is very important.

3. Application of balance training to fall risk in elderly with DPN

A report by the Quality Standards Subcommittee of the American Academy of Neurology indicated that people with DPN have probable (level B evidence) risk of falling and that those with disorders of balance and gait have established (level A evidence) risk of falling [15]. Ghanavati et al. [16] found that balance and physical coordination in elderly with DPN were lower significantly than without DPN. Body balance was affected by many factors, including the vestibular, visual, proprioceptive, lower extremity muscle strength and range of motion and so on. Among them, the decline of proprioceptive, vestibular and lower extremity muscle strength were the main reasons for impaired balance in elderly with DPN [17]. At present, studies that were mainly to promote the recovery of balance and to reduce its risk of falling in elderly with DPN were through the following balance training methods.

3.1. Proprioceptive training

3.1.1. Nerve conduction training

Research showed that the walking ability [18] and fall risk of DPN [19] and its degree of neuropathy were positively correlated. DPN could cause demyelination and axonal degeneration of nerve fibers, slowed nerve conduction velocity, delayed reflex reaction time, causing balance function decline. On the one hand, lower extremity aerobic exercise training could control glycemic in elderly with DPN [20] and disrupt the normal progression of DPN. On the other hand, it can improve lower limb muscle oxygen uptake and the sensitivity of nerve conduction and proprioceptors during walking, shorten the reaction time of reflection, enhanced body balance function, thereby reducing the risk of falling. Dixit et al. [21] had treated 87 elderly with DPN aerobic exercise training for 8 weeks, the frequency of each exercise session was 3–6 days of the week of moderate intensity treadmill exercises, the results showed the degree of neuropathy was significantly reduced, a

significant increase in the patients' epidermal nerve fiber branch and nerve conduction velocity.

3.1.2. Nerve perception training

Because of a lesion or dysfunction of the nervous system, elderly with DPN suffer foot pain and plantar baroreceptor loss, causing their lower limb proprioception information errors, and foot posture changed significantly, thereby resulting in walking posture instability and risk of falls increased. Mickle et al. [22] showed that the incidence of foot pain in the elderly with a history of falls was significantly higher than that without pain. Infrared light therapy and tactile stimulation technology training by improving nerve perception function of elderly with DPN, enhanced the attitude control capability, thereby improving balance and reducing the risk of falling. Infrared light therapy using of infrared thermal effects of human tissue depth, could expand blood vessels, increase blood flow, block the vicious cycle of pain, relieve pain, improve the perception of foot nerve function and orientation control. Powell et al. [23] found that infrared light therapy could significantly reduce foot pain in elderly with DPN, enhance balance, and reduce the risk of falling. Plantar stimulation technique was the use of noise stimulation, electrical stimulation and mechanical stimulation and so on, to enhance the elderly with DPN foot and lower limb proprioception perception thresholds, and enhance its balance. Khaodhiar et al. [24] used mechanical stimulation to the specific areas of the foot, specifically the heel, ball, and big toe regions in 20 diabetic patients with moderate to severe neuropathy, the results showed that a significant increased in plantar vibration sense, tactile and proprioceptive threshold. Najafi et al. [25] used electrical stimulation to the planter in 56 mild to moderate DPN, treatments were administered 5 times per week for 6 weeks, the results showed that a significant increased in proprioceptive threshold and postural stability. Menz et al. [26] applicated the passive tactile cues to ankle, calf and knee in 10 elderly with DPN, The stimulus produced a shear force on the skin of less than 0.02 N, insufficient to provide a stabilizing reaction, the results showed that a significant increase in postural stability in elderly with DPN.

3.2. Vestibular training

Elderly with DPN due to aging and neuropathy factors, vestibular nerve damaged, leading to vestibular dysfunction. Kim et al. [27] found that the incidence of vestibular dysfunction in elderly patients with DPN was nearly 60%, which could cause declined information integration capabilities of brain, reduced ability to control body balance, leading to increased risk of falls. Fall risk in the diabetes with vestibular dysfunction was 2.3 times than that without vestibular dysfunction [28]. Vestibular function training in elderly with DPN, could make a correct understanding of sensory signals into the brain quickly and make the right judgment motion response by sensory reorganization, and enhance balance function, thus reducing the risk of falling. Akbari et al. [29] had treated 20 patients with DPN whose average age was 56 years with vestibular training exercise, such as rotational movement, posture reactive movement, after 20 weeks, the overall ability to stabilize, ability to stabilize before and around of the

patients were significantly increased. Chang et al. [30] have treated 19 elderly with DPN whose average age was 73 years with eight weeks of low intensity sense of place, a sense of distance training experience and other vestibular function, the results showed that the intervention group dynamic and static balance were significantly improved.

3.3. Lower limb strength training

3.3.1. Lower extremity weight training

Lower extremity weight training was an exercise training that could enhance lower limb muscle contraction by resistance exercise, increased number of groups and training intensity and so on. Elderly due to aging, muscle degeneration leads to weakness and loss, especially in the lower limb [31]. When merge DPN, neuropathy could cause foot and lower limb muscle atrophy, and further lead to lower limb weakness and an increased risk of falls. Wang Liancheng et al. [32] found that older people who had a history of falls decreased significantly in its lower extremity muscle strength. Lower extremity weight training, to enhance lower extremity muscle strength plays a vital role in maintaining a stable posture. Michael et al. [33] have treated 29 patients with DPN with sat up training, stair climbing and other weight-bearing exercise for 12 weeks and found that weight training could significantly improve the lower limbs of patients with DPN walking ability, and relatively more effective than non-weight training. But there was still not enough evidence to prove that lower extremity weight training exercise training only can enhance the elderly balance and reduce the occurrence of falls [34]. So other balance training should be combined with to enhance the effect of its reduced risk of falls in elderly with DPN.

3.3.2. Ankle strategy training

Elderly with DPN because of neuropathy, ankle dorsal flexor and external rotation muscle strength decreased, ankle regulate appetite, resulting in poor static balance function in elderly with DPN, which led to their increased risk of falls. Ankle strategy training could enhance muscle strength of foot and ankle in elderly with DPN, thereby enhancing their ability to walk and balance. Cristina et al. [35] have treated 46 DPN with a training that aimed at improving foot and ankle muscle strength, range of motion and function for 12 weeks, gradual and progressive difficulty is offered to the patient, the results showed the walking ability, range of motion significantly improved. But except ankle weakness, there are also the hip, knee weakness in elderly with DPN, whether ankle strategy training only could enhance its balance to be further verified. Jaebum et al. [36] showed that ankle orthoses which provide medial-lateral support did not appear to change ankle inversion/eversion proprioceptive thresholds or unipedal stance time in elderly with DPN.

3.4. Mixed sports training

Mixed sports training refers to training methods include both lower limb muscle strength and proprioceptive training. Allet et al. [37] have treated 71 elderly with DPN with mixed sports training for 6 months which included strength and endurance exercises (sitting to standing, walking up and down a slope

and stair climbing) and balance and walking tasks (one leg stance, different kinds of walking), the results showed that lower extremity muscle strength, range of motion and balance function had been significantly improved in the intervention group. Lee et al. [38] found that, compared with proprioceptive training alone, the mixed sports training could better improve the balance function, increase lower extremity muscle strength and control glycated hemoglobin in elderly with DPN. Meanwhile, mixed sports training did not increase the DPN patients the incidence of foot ulcers and falls, with some security. 79 DPN patients performed mixed sports training, after one year of follow-up survey, the incidence of foot ulcers [39] and the incidence of falls [40] between the two groups were no statistically significant difference.

4. Methods in establishing the effectiveness of balance training

4.1. Forms of exercise

The muscle loss and consolidated compliance osteoporosis are common in most of elderly with DPN. So the movement should be simple and safe, easy stick, moderate exercise intensity, to avoid harm trauma principle. Prescribing guidelines in older patients in USA recommended [41] elderly diabetic patients should choose a lower resistance, low intensity, using the major muscle groups of the movement.

4.2. Duration of exercise

Research showed that [42] exercise time in different skeletal muscle of type 2 diabetes and IRS-2 protein phosphorylation had different effects, and 40 min of duration of the effect was the best.

4.3. Adherence of exercise

Exercise adherence directly determined the therapeutic effect of exercise therapy, which was impacted by their understanding of physical therapy and social support and other factors [43]. Studies had shown that the collective form of movement [44], music mediated sports training [45] and home exercise training [46] could improve older patients exercise motivation, so choose a collective form of exercise, music mediated sports training and family-style campaign training and other forms may be effective to improve the adherence in elderly with DPN.

5. Conclusion

Proprioception training, vestibular training, lower limb strength training and mixed sports training could enhance balance and reduce its risk of falling in elderly with DPN from different aspects, were worthy of further promotion and application. When the therapist applies the balance training to elderly patients with DPN, they should focus on the features of different kinds of balance training. Due to the safety and effectiveness, Proprioceptive training can be applied to

moderate to severe neuropathy in elderly patients. Vestibular training is more suitable for younger DPN patients, when is applied to elderly patients, we should pay attention to their safety, and should choose low-intensity training. Weight training could significantly improve the lower limbs of patients with DPN walking ability, and relatively more effective than non-weight training, should be combined with to enhance the effect of its reduced risk of falls in elderly with DPN, and there are more ample evidence that mixed training are relatively more effective in improving balance function, reducing its fall in elderly with DPN. Simultaneously, we should combine its own characteristics in elderly with DPN to enhance the effectiveness of balance training from the motion in the form, duration, adherence, and so on.

Conflicts of interest statement

The authors declare that they have no conflict of interest.

REFERENCES

- [1] People's Republic of China Statistics Bureau. 2010 Main sixth national census data bulletin: No. 1 [R]. 2011-04-28.
- [2] Sheng Zhouying, Jia Chi Min. Epidemiology of diabetes in the elderly. *Chin J Geriatr* 2007;26(8):565-6.
- [3] Halawa MR, Karawagh A, Zeidan A, Mahmoud AE, Sakr M, Hegazy A. Prevalence of painful diabetic peripheral neuropathy among patients suffering from diabetes mellitus in Saudi Arabia. *Curr Med Res Opin* 2010;26(2):337-43.
- [4] Jambart S, Ammache Z, Haddad F, Younes A, Hassoun A, Abdalla K, et al. Prevalence of painful diabetic peripheral neuropathy among patients with diabetes mellitus in the Middle East region. *J Int Med Res* 2011;39(2):366-77.
- [5] Won JC, Kwon HS, Kim CH, Lee JH, Park TS, Ko KS, et al. Prevalence and clinical characteristics of diabetic peripheral neuropathy in hospital patients with type 2 diabetes in Korea. *Diabet Med* 2012;29(9):e290-6.
- [6] Ites KI, Anderson EJ, Cahill ML, Kearney JA, Post EC, Gilchrist LS. Balance interventions for diabetic peripheral neuropathy: a systematic review. *J Geriatr Phys Ther* 2011;34(3):109-16.
- [7] Schwartz AV, Sellmeyer DE, Ensrud KE, Cauley JA, Tabor HK, Schreiner PJ, et al. Older women with diabetes have an increased risk of fracture: a prospective study. *J Clin Endocrinol Metab* 2001;86(1):32-8.
- [8] Lieberman D, Friger M, Lieberman D. Rehabilitation outcome following hip fracture surgery in elderly diabetics: a prospective cohort study of 224 patients. *Disabil Rehabil* 2007;29(4):339-45.
- [9] Pijpers E, Ferreira I, de Jongh RT, Deeg DJ, Lips P, Stehouwer CD, et al. Older individuals with diabetes have an increased risk of recurrent falls: analysis of potential mediating factors: the longitudinal ageing study Amsterdam. *Age Ageing* 2012;41(3):358-65.
- [10] Ekstrom W, Al-Ani AN, Saaf M, Cederholm T, Ponzer S, Hedstrom M. Health related quality of life, reoperation rate and function in patients with diabetes mellitus and hip fracture - a 2 year follow-up study. *Injury* 2013;44(6):769-75.
- [11] Cavanagh PR, Derr JA, Ulbrecht JS, Maser RE, Orchard TJ. Problems with gait and posture in neuropathic patients with insulin-dependent diabetes mellitus. *Diabet Med* 1992;9(5):469-74.
- [12] DeMott TK, Richardson JK, Thies SB, Ashton-Miller JA. Falls and gait characteristics among older persons with peripheral neuropathy. *Am J Phys Med Rehabil* 2007;86(2):125-32.
- [13] Mei Xiejun, Rihua Xiao, Pinggen Li. A prospective study of patients with diabetes fall. *Clin Med* 2011;31(3):76-8.
- [14] Lu Dong, Jie Zhou, Guohui Xu. Advances in nursing elderly inpatients falls. *Chin J Rehabil Theory Pract* 2012;18(1):30-2.
- [15] Thurman DJ, Stevens JA, Rao JK. Practice parameter: assessing patients in a neurology practice for risk of falls (an evidence-based review): report of the Quality Standards Subcommittee of the American Academy of Neurology. *Neurology* 2008;70(6):473-9.
- [16] Ghanavati T, Shaterzadeh YM, Goharpey S, Arastoo AA. Functional balance in elderly with diabetic neuropathy. *Diabetes Res Clin Pract* 2012;96(1):24-8.
- [17] Lafond D, Corriveau H, Prince F. Postural control mechanisms during quiet standing in patients with diabetic sensory neuropathy. *Diabetes Care* 2004;27(1):173-8.
- [18] Lin SI, Chen YR, Liao CF, Chou CW. Association between sensorimotor function and forward reach in patients with diabetes. *Gait Posture* 2010;32(4):581-5.
- [19] Richardson JK. Factors associated with falls in older patients with diffuse polyneuropathy. *J Am Geriatr Soc* 2002;50(11):1767-73.
- [20] Streckmann F, Zopf EM, Lehmann HC, May K, Rizza J, Zimmer P, et al. Exercise intervention studies in patients with peripheral neuropathy: a systematic review. *Sports Med* 2014;44(9):1289-304.
- [21] Dixit S, Maiya AG, Shastri BA. Effect of aerobic exercise on peripheral nerve functions of population with diabetic peripheral neuropathy in type 2 diabetes: a single blind, parallel group randomized controlled trial. *J Diabetes Complicat* 2014;28(3):332-9.
- [22] Mickle KJ, Munro BJ, Lord SR. Foot pain, plantar pressures, and falls in older people: a prospective study. *J Am Geriatr Soc* 2010;58(10):1936-40.
- [23] Powell MW, Carnegie DH, Burke TJ. Reversal of diabetic peripheral neuropathy with phototherapy (MIRE™) decreases falls and the fear of falling and improves activities of daily living in seniors. *Age Ageing* 2006;35(1):11-6.
- [24] Khaodhiar L, Niemi JB, Earnest R, Lima C, Harry JD, Veves A. Enhancing sensation in diabetic neuropathic foot with mechanical noise. *Diabetes Care* 2003;26(12):3280-3.
- [25] Najafi B, Crews RT, Wrobel JS. A novel plantar stimulation technology for improving protective sensation and postural control in patients with diabetic peripheral neuropathy: a double-blinded, randomized study. *Gerontology* 2013;59(5):473-80.
- [26] Menz Hylton B, Lord Stephen R, Fitzpatrick Richard C. A tactile stimulus applied to the leg improves postural stability in young, old and neuropathic subjects. *Neurosci Lett* 2006;406(1-2):23-6.
- [27] Kim SK, Lee KJ, Hahm JR, Lee SM, Jung TS, Jung JH, et al. Clinical significance of the presence of autonomic and vestibular dysfunction in diabetic patients with peripheral neuropathy. *Diabetes Metab J* 2012;36(1):64-9.
- [28] Agrawal Y, Carey JP, Della SC, Schubert MC, Minor LB. Diabetes, vestibular dysfunction, and falls: analyses from the National Health and Nutrition Examination Survey. *Otol Neurotol* 2010;31(9):1445-50.
- [29] Akbari M, Jafari H, Moshashae A, Faist M. Do diabetic neuropathy patients benefit from balance training? *J Rehabil Res Dev* 2012;49(2):333-8.
- [30] Song CH, Petrofsky JS, Lee SW, Lee KJ, Yim JE. Effects of an exercise program on balance and trunk proprioception in older adults with diabetic neuropathies. *Diabetes Technol Ther* 2011;13(8):803-11.

- [31] Leveille SG, Jones RN, Kiely DK, Hausdorff JM, Shmerling RH, Guralnik JM, et al. Chronic musculoskeletal pain and the occurrence of falls in an older population. *JAMA* 2009;302(20):2214–21.
- [32] Wang Lian-Cheng, Zhang Wei, Zhang Li-Qin. Falls in elderly patients with lower limb muscle strength changes. *Tianjin Pharm* 2012;40(9):938–9.
- [33] Mueller Michael J, Tuttle Lori J, LeMaster Joseph W, Strube Michael J. Weight-bearing versus nonweight-bearing exercise for persons with diabetes and peripheral neuropathy: a randomized controlled trial. *Arch Phys Med Rehabil* 2013;94(5):829–38.
- [34] Orr R. Contribution of muscle weakness to postural instability in the elderly: a systematic review. *Eur J Phys Rehabil Med* 2010;46(2):183–220.
- [35] Sartor Cristina Dallemole, Watari Ricky, Pássaro Anice Campos, Picon Andreja Paley. Effects of a combined strengthening, stretching and functional training program versus usual-care on gait biomechanics and foot function for diabetic neuropathy: a randomized controlled trial. *BMC Musculoskelet Disord* 2012;5(19):13–36.
- [36] Son Jaebum, Ashton-Miller James A, Richardson James K. Do ankle orthoses improve ankle proprioceptive thresholds or unipedal balance in older persons with peripheral neuropathy. *Am J Phys Med Rehabil* 2010;89(5):369–75.
- [37] Allet L, Armand S, de Bie RA, Golay A, Monnin D, Aminian K, et al. The gait and balance of patients with diabetes can be improved: a randomised controlled trial. *Diabetologia* 2010;53(3):458–66.
- [38] Lee K, Lee S, Song C. Whole-body vibration training improves balance, muscle strength and glycosylated hemoglobin in elderly patients with diabetic neuropathy. *Tohoku J Exp Med* 2013;231(4):305–14.
- [39] Lemaster JW, Mueller MJ, Reiber GE, Mehr DR, Madsen RW, Conn VS. Effect of weight-bearing activity on foot ulcer incidence in people with diabetic peripheral neuropathy: feet first randomized controlled trial. *Phys Ther* 2008;88(11):1385–98.
- [40] Kruse RL, Lemaster JW, Madsen RW. Fall and balance outcomes after an intervention to promote leg strength, balance, and walking in people with diabetic peripheral neuropathy: “feet first” randomized controlled trial. *Phys Ther* 2010;90(11):1568–79.
- [41] McDermott AY, Mermitz H. Exercise and older patients: prescribing guidelines. *Am Fam Physician* 2006;74(3):437–44.
- [42] Hong Hua, Yaoguang Wang, Renyong Guo. Different exercise time in skeletal muscle of type 2 diabetic rats IRS a two phosphorylated protein content and impact. *Chin J Sports Med* 2010;29(3):335–7.
- [43] Ruchat SM, Mottola MF. The important role of physical activity in the prevention and management of gestational diabetes mellitus. *Diabetes Metab Res Rev* 2013-07-01;29(5):334–46.
- [44] Meng Gong-Lin, Deng Yu-Yun, Chen Hong-Tao, Jing-Liu. Collective exercise intervention to improve the treatment of type 2 diabetic patients. *J Nurs Adm* 2009;9(7):37–40.
- [45] Karageorghis CI, Terry PC, Lane AM, Bishop DT, Priest DL. The BASES expert statement on use of music in exercise. *J Sports Sci* 2012;30(9):953–6.
- [46] Opdenacker J, Boen F, Coorevits N, Delecluse C. Effectiveness of a lifestyle intervention and a structured exercise intervention in older adults. *Prev Med* 2008;46(6):518–24.