Published online 2022 March 20 **Original Article**

The Effect of Physical Activity, Neuropathy, and Gender on People with Diabetes on Balance: A Cross-sectional Study

Zahra Kosarian[1,2], Mehrnoosh Zakerkish[3], Mohammad-Jafar Shaterzadeh Yazdi[1,*], Saeed Hesam[4] and Mohammad Mehravar[1]

[1] Musculoskeletal Rehabilitation Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[2] Student Research Committee, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[3] Diabetes Research Center, Health Research Institute, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
[4] Department of Biostatistics and Epidemiology, School of Public Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

* ***Corresponding author:*** Mohammad-Jafar Shaterzadeh Yazdi, Musculoskeletal Rehabilitation Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran. Email: shaterzadeh.pt@gmail.com

Received 2021 September 19; **Revised** 2021 October 18; **Accepted** 2022 January 19.

Abstract

Background: Diabetes mellitus (DM) is one of the most common chronic non-communicable diseases (NCD).
Objectives: The present study aimed to investigate the relationship between demographic and clinical data with balance impairments in people with diabetic peripheral neuropathy (DPN), considering the importance of early detection of balance impairments in this population.
Methods: Forty-three patients with DPN were evaluated in this cross-sectional study. Age, disease duration, height, weight, and physical activity, along with blood sugar samples and neuropathy disability scores were collected to explore correlations with the balance evaluation system test (BESTest) in this population.
Results: A significant weak to moderate correlations was found between physical activity (p-value=0.046/ CC= 0.286), severity of neuropathy (p-value=0.025/ CC= -0.317), and gender (p-value=0.032/ CC= -0.311) with BESTest, using multivariate linear regression analysis.
Conclusion: It is recommended that diabetic patients with a sedentary lifestyle, more severe scores on neuropathy screening instruments, and female patients be referred for early screening of balance disorders regardless of age and disease duration. Also, increasing physical activity to prevent balance impairments in the future can be recommended.

Keywords: Balance, Diabetes, Diabetic polyneuropathy, Postural control

1. Background

Diabetes mellitus (DM) is one of the most common chronic non-communicable diseases (NCD). According to the latest estimates, the prevalence of DM is rapidly increasing among other NCDs, reaching 592 million by 2035 (1,2). One of the most common and chronic consequences of DM is diabetic peripheral neuropathy (DPN), which affects approximately 50% of those suffering from diabetes. Distal symmetrical neuropathy (DSN) is the most common type of neuropathies (3). DSN destroys or wastes afferent nerve fibers of lower extremities which results in defection or loss of accurate proprioceptive feedback, body instability, balance disorders, and gait disturbances (3,4). Numerous studies have identified these consequences as risk factors for falls down (1,5-7) which alone may increase the risk of falls by 2 to 4 times in healthy elderly (8,9). Powell et al. (10) found that 29% of people with DPN fell in the past year of which 73% fell twice or more. Previous studies have reported that the possibility of injury following a fall in the DPN population is 15 times more than healthy and diabetic individuals without neuropathy (11-13). The double risk of falling in these people, in addition to fear avoidance behavior, followed by decreased daily activity and quality of life (14-16) leads to a decrease in tissue healing rate after injury, infection, gangrene, or amputation (4,17). Therefore, preventing falls in people with diabetic neuropathy is very important, which requires an early diagnosis of balance disorders in this population (18,19).

Balance control is a complex interaction between sensory and motor systems. The sensory systems involved in this process are the somatosensory, visual, and vestibular systems (20). Balance impairment occurs if any of the above-mentioned sensory systems are affected, and falls will be expected if diagnosis and treatment are postponed (18,19). Some of the known risk factors for falls include peripheral neuropathy, physical performance decline, and visual impairments, which are common among people with diabetes. Studies have shown that the risk of falling in the diabetic population is higher than in the control group (6,7). Furthermore, fractures after falling are more common in this population (7).

The existence of balance impairments in the DM population has been well documented by previous studies (13,18,21-25). However, the assessment procedure requires balance assessing instruments,

questionnaires, and experts which is a time-consuming process due to the importance of early screening of balance disorders. Additionally, it is accepted that a relationship between demographic, habitual, and clinical data (age, physical activity, blood glucose level, neuropathy severity) was found with balance (13,19,21,24,26-29). Since these data are easily and promptly obtained by the history of the patient, we can determine factors having the conditions for predicting balance changes in this population, we will be able to identify people at risk for balance impairments and falling sooner and refer them to the appropriate medical centers for further examination and treatment.

2. Objectives

The present study aimed to detect the relationship between balance performance with demographic and clinical characteristics of patients with diabetic neuropathy.

3. Methods

3.1. Study Design

This descriptive-analytic study was conducted at Musculoskeletal Rehabilitation Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran. The study protocol was approved by the Human Research Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (IR.AJUMS.REC.1397.436).

3.2. Participants

The participants of this cross-sectional survey were selected from diabetic patients who were referred to Golestan Hospital and Diabetes Research Center in Ahvaz, from September 2020 to March 2021. At the first stage, 74 patients were identified, 22 of whom refused to participate in the study for personal reasons, and 9 were excluded from the study due to having a pacemaker, total knee arthroplasty, active breast cancer, lower back pain, lower limb lymphedema, and foot ulcer. Finally, 43 patients including 28 women and 15 men were participated in the study. The inclusion criteria were existence of diabetes diagnosed by endocrinologist and neuropathy confirmed by laboratory and clinical tests. Participants were excluded from the study if they suffered any of the followings: foot ulcers, dizziness, visual acuity improvement less than 20/70, partial or total amputation of lower limbs, and a history of cardiovascular, vestibular, musculoskeletal, rheumatologic, or neurological disorders (other than DN) (11, 18, 19, 23, 24, 30, 31). A written informed consent was obtained from the participants before conducting the study.

3.3. Demographic information:

A part of this information was obtained by completing a questionnaire including personal information, medical history, habits, and daily activities. Afterwards, height and weight of the participants were taken using meter and digital scales, respectively. The body mass index (BMI) for each participants was calculated by dividing the weight (kg) by the square of the height (m^2). Disease duration was considered as the duration (years) the patient has been diagnosed with diabetes.

3.4. Blood glucose:

The participants were asked to have a blood test at Ahvaz Golestan Hospital, to measure fasting blood glucose (FBS) and blood glucose two hours after having a meal (2hpp).

3.5. Neuropathy assessment:

The criteria of diagnosing DPN in this study were one of the followings:

1. Results of nerve conduction studies for Sural (cut offs: a delay of uttermost 4msec, and 10μv least amplitude) and Tibial (cut offs: 38m/sec least conduction velocity, and 2mv least amplitude) nerves.

2. Score of Neuropathy Disability Score (NDS) (32-36): This contains two sub-scales: a)Reflex assessment for Achill tendon, and b)Sensory assessments including *vibration* (measured with 128 Hz tuning fork) , *pain* (assessed by pin-prick test), and *temperature* (tested with warm and cold water). NDS scores equal to/higher than 3 indicates the presence of neuropathy. Mild neuropathy is indicated by a score 3-5, moderate neuropathy is inferred from a score of 5-6, and a score higher than 6 demonstrates a sever neuropathy.

3.6. Balance assessment:

Balance evaluation system test or BESTest is a functional balance questionnaire developed by Horak et al in 2009, aimed to evaluate foundational systems involved in balance control. It contains 36 isolated items (27 task) situated in 6 sub-groups shown in figure 1. Item-level scores could range from zero to three. Maximum scores for each of the 6 sub-groups are 15, 21, 18, 18, 15, and 21; therefore, the total test ranges from 0-108 where increase in BESTest score means better balance performance and less impairment. Intraclass correlation coefficient (ICC) for interrater reliability was calculated 0.91 as a hole, and between 0.79 and 0.96 for each part. Kendal coefficient of concordance among raters was reported to be 0.46 to 0.100 for each part; additionally, concurrent validity correlation between BESTest and ABC was 0.636 ($p<0.01$) (37).

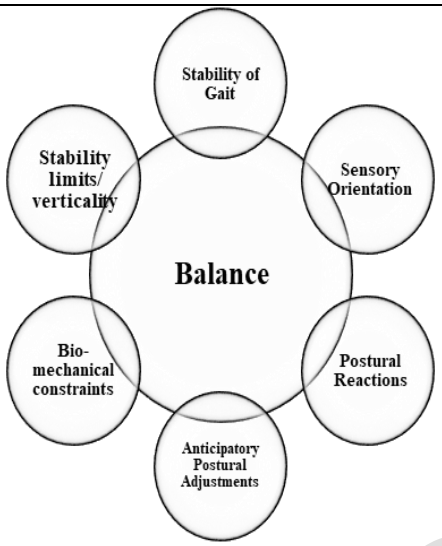

Figure 1. Sub-groups of balance evaluation system test (BESTest)

3.7. Statistical analysis:

Mean, median, and inter-quartile range were used to describe the data. In order to assess the normality of the data, Kolmogorov-Smirnov test and quartile-quartile plot were performed. Nonparametric tests were utilized, according to the matter that BESTest data were deviated from normal values. Furthermore, in order to perform multivariate analysis of the data, due to the fact that the data was skewed to the left, the variables were skewed to the right using the following quotation. Afterwards, deviation from normality was eliminated using variable transformation.

Variable transformation quotation = max + 1 – variable

Mann-Whitney test and Spearman correlation coefficient were used to assess the strength between associations of two variables. In order to find the best fit multivariate model, backward elimination linear regression was utilized. The level of significance was set at 0.05. All analysis were performed using SPSS software version 22.

4. Results

4.1. Descriptive information

Twenty eight female and 15 male making a total number of 43 people suffering DPN participated in this study. The descriptive statistics of the participant's demographic information, laboratory and balance tests are given in table 1.

4.2. Univariate analysis

Table 2 reveals the result of Spearman's correlation and Mann-Whitney test analysis. Due to the results, and by using univariate analysis, physical activity, NDS of the participants, and female gender were correlated with BESTest score, with p-values of 0.043, 0.016, and 0.049, respectively. Hence, according to correlation coefficients of univariate analysis, with 0.309 unit increase in weekly physical activity, and 0.366 unit decrease in NDS score, BESTest score increases by one point.

4.3. Multivariate analysis

By using backward elimination linear regression, multivariate analysis was conducted (Table 3). As presented in table 3, three variables of physical activity, NDS, and gender were significantly correlated with BESTest score and entered in the model. In other words, the simultaneous existence of the abovementioned factors, indicated a significant

Table 1. Descriptive analysis of demographic characteristic, laboratory, and balance tests of participants

Variable	Mean (SD)	Median	Maximum	Minimum
Age (year)	57.65 (12.79)	59	73	27
Height (cm)	163.9 (26.27)	162	185	151
Weight (kg)	78.63 (17.76)	80	102.9	52.8
BMI (kg/m2)	29.42 (7.08)	29.38	42.83	18.99
Disease duration (year)	12.16 (7.11)	10	30	1
Physical activity (min/week)	77.67 (132.81)	0	480	0
NDS	6.04 (2.29)	7	9	0
FBS (mg/dL)	170.72 (74.69)	144	330	74
2hpp (mg/dL)	253 (95.89)	236	420	131
BESTest score	85.76 (25.34)	92	108	23

BMI: body mass index, NDS: neuropathy disability score, FBS: fasting blood sugar, 2hpp: blood glucose 2 hours post prandial, BESTest: balance evaluation system test

Table 2. Results of Spearman's correlation and Mann-Whitney test analysis

Variable		ρ	p-value
Age		-0.224	0.149
BMI		-0.234	0.131
Disease duration		-0.137	0.382
Physical activity		0.309	0.043
NDS		-0.366	0.016
FBS		0.199	0.200
2hpp		0.190	0.222
Gender*	Female	80.50 ± 25.10 91 (29.5)	0.049
	Male	95.60 ± 9.22 96 (15)	

BMI: body mass index, FBS: fasting blood sugar, NDS: neuropathy disability score, ρ: Spearman's correlation coefficient, 2hpp: blood glucose 2 hours post prandial
The statistically significant values are shown in bold
*Mann-Whitney test was performed due to the descriptive essence of the variable

correlation with BESTest score. The most influential factor of this model was NDS score (p-value 0.025/ Beta: 0.317), which was found that with 0.317 unit decrease in NDS score, one point was added to the balance score. The second influential factor was gender (p-value 0.032); accordingly, in female participants, balance score was significantly lower (Beta: 0.311). Physical activity was the third influential factor (p-value 0.046/ Beta: 0.286), so that we found a 0.286 unit increase in physical activity for every one point increase in point BESTest score. In other words if patient exercises for approximately 171.6 min/week, then BESTest score was increase by 9.2% (10 points).

Table 3. Results of stepwise linear regression analysis

Variable	B	95% CI	Beta	p-value
Physical activity	0.004	0.001, 0.009	0.286	0.046
NDS	-0.313	-0.585, -0.041	-0.317	0.025
Gender	-1.351	-2.578, -0.123	-0.311	0.032

NDS: neuropathy disability score, Beta: correlation coefficient
The statistically significant values are shown in bold

5. Discussion

The current study was aimed to discover relationships between demographic and clinical data with balance impairments in people with diabetic neuropathy; for the purpose of early detecting patients prone to balance disorders, to prevent falls in this population. Accordingly, we performed correlation models to detect whether patients age, disease duration, BMI, NDS score, physical activity, FBS, and 2hpp had significant relations with BESTest score. The results of multivariate analysis showed that the presence of three factors of physical activity, neuropathy severity, and gender simultaneously and independently, is associated with balance performance.

The results of our study showed significant correlation between physical activity and balance in people with DPN. Several studies have concluded that proper physical activity displays an important role in reversing the progression and development of neuropathy in people with diabetes (30, 38-40). Likewise, results from a RCT conducted by Morrison et al. (41) demonstrated an improvement in dynamic balance following 12 weeks of aerobic exercise. To the best of the author's knowledge, there were no studies evaluating the relationship between physical activity and balance performance. Therefore, we conclude there may be a significant association between the hours DPN patients exercised in a week, and balance performance. By interpreting the results of regression analysis utilized in our study, it was deduced that there was approximately 171.6 min/week (24.5 minutes daily) increase in physical activity for 9.2% (10 point) increase in BESTest score, in other words balance performance.

In our study, the severity of neuropathy which was documented via NDS, demonstrated negative correlation with balance disorders. To be specific, the lower the severity of the neuropathy, the better the balance performance. This finding was consistent with several studies which found significant correlation between vibration perception threshold score (28), Michigan neuropathy screening instrument (29, 42), Valk score (21, 23), some NCV parameters (19), and diabetic neuropathy examination questionnaire (24) and balance impairments. In contrast, the results from the study of Nardone et al. (13) did not find any correlation between balance impairments and NDS score, and electrophysiological assessment of large motor, and sensory fibers of lower limb.

There was a significant correlation between female sex and balance impairments, according to our study. Baharlouei et al (43) found similar results in elderly population. To the best of our knowledge, there were no similar studies investigating the

association between gender and balance impairments in people with DPN. Although a study directed by Kukidome et al. (27) revealed a significant correlation between female sex and risk of falls in people with diabetic neuropathy. Since fall is a consequence of balance impairments, it can be concluded that the finding of our study is in line with the result of the study conducted by Kukidome at al. (27).

Consistent with the finding of our study, Toosizadeh et al. (28) did not find any significant correlations between stabilogram diffusion parameters and age. Additionally, in a study performed by Yamamoto et al. (19) there were no significant correlation between most GRAVICHART parameters and age, however; they found significant correlations between only 2 of 6 GRAVICHART parameters and age. Also Simoneau et al. (25) found a significant correlation between postural instability and aging.

In contrast to the results of the study conducted by Toosizadeh et al (28), our analysis did not displayed a significant association between disease duration and balance performance. The result is consistent with studies conducted by Yamamoto et al.(19), and Kukidome et al.(27), which did not find significant correlation in most of the assessed balance measures in their study. This lack of association may be due to the fact that during the lifespan of a diabetic patient, coping and compensations may occur to improve the balance controlling function, as it has been clarified that this people have visual dependency and compensated proximal hip and pelvis musculature for balance control instead of distal ankle muscles which are most affected by the disease(18, 23).

In the current study, we used FBS and 2hpp as indicators for glycemic control. As shown in tables 2 and 3, there were no significant correlation was observed between glycemic control and balance impairments. This finding was in line with the study mediated by Timar et al (29) which did not find any correlations between HbA1C –as an indicator of glycemic control- and balance performance. On the contrary, Yamamoto et al. (19) and Emam et al. (26) found that HbA1C was significantly correlated with balance control. In case of falls, the results of Tilling et al. (44) revealed a significant correlation between A1C and risk of falls. On the contrary, and similar to our results, Miller et al. (45) and Schwartz et al. (46) found no correlation between A1C and risk of falls; concluding that there were no relationship between poor glycemic control and falls.

The results of the current study revealed no correlations between BMI and balance problems. Toosizadeh et al. (28) also did not find any correlations between BMI, height, or weight of the participants with balance ability; whereas, Yamamoto et al. (19) found them significantly correlated. According to the results of current study and the study conducted by Toosizadeh et al. (28) , BMI does not affects balance ability in people with DPN.

5.1. Limiations and recommendation for future studies

Although, the number of patients was sufficient for statistical analysis, we suggest recruiting more patients in future studies in order to investigate the association between multiple factors and balance control in DPN population. Furthermore, as HbA1C has the ability to reveal blood glucose in the last three months, it may be a better index for evaluating glycemic control; therefore, it is suggested to use HbA1C to probe the relationship between glycemic control and balance control. Moreover, the authors suggest exploring this association not only in DPN patients, but also in diabetic patients without neuropathy.

6. Conclusion

Our study confirmed the association between physical activity, neuropathy severity, and gender with balance in DPN patients, in such a way that with decrease in physical activity, increase in NDS, and having a female gender, balance disorders are more likely to develop. Accordingly, it is recommended that in order to prevent the irreversible consequences, diabetic patients presenting singly or concurrently lesser physical activity, more sever neuropathies, and female gender, should be aware of their balance situation and referred for early screening of balance disorders; regardless of their age or duration of disease. Interestingly, according to the results of this study one of the predictors of balance disorders in these people was physical activity in such a way that with 9.2% increase in BESTest score, there is approximately 24.5 min/day increase in physical activity. Therefore, this suggestion could be made to diabetic patients that it is best to increase your physical activity to prevent future balance impairments.

Acknowledgments

This study was funded by Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran (Grant Number: Pht-9716). The authors express their appreciation to Musculoskeletal Rehabilitation Research Center's staff for their great cooperation.

Footnotes

Conflicts of Interest: None

References

1. Awotidebe TO, Ativie RN, Oke KI, Akindele MO, Adedyin RA, Olaogun MO, et al., Relationships among exercise capacity,

dynamic balance and gait characteristics of Nigerian patients with type-2 diabetes: an indication for fall prevention. *J Exer Rehabil*. 2016.; **12**(6): 581-588. doi: 10.12965/jer.1632706.353 [PMID: 28119881]
2. Forouhi, NG ,Wareham NJ, Epidemiology of diabetes. *Medicine*. 2014. **42**(12): 698-702. doi: 10.1016/j.mpmed.2014.09.007. [PMID: 25568613]
3. Jernigan SD, Pohi PS, Mahnken JD, Kluding PM., Diagnostic accuracy of fall risk assessment tools in people with diabetic peripheral neuropathy. *Phys Ther,* 2012; **92**(11): 1461-1470. doi: 10.2522/ptj.20120070. [PMID: 22836004]
4. Vinik AI, Strotmeyer ES, Nakave AA, Patel CV., Diabetic neuropathy in older adults. *Clin Geriatr Me.* 2008; **24**(3): 407-435. doi: 10.1016/j.cger.2008.03.011. [PMID: 18672180].
5. Mantovani MM, Pinto MDC, Lorençoni RMR, Palma MR , Ribeiro FE, Fergonesi CEPT. Risk of Falls in People with Diabetes Mellitus. *J Diabetes Res*, 2015;2(4): 1-3.doi: 10.23937/2377-3634/1410040
6. Wallace C, Reiber GE, LeMaster J, Smith DG, Sullivan K, Hayes S, et al. Incidence of falls, risk factors for falls, and fall-related fractures in individuals with diabetes and a prior foot ulcer. *Diabetes Care*, 2002; **25**(11): 1983-1986. doi: 10.2337/diacare.25.11.1983. [PMID: 12401743].
7. Yau RK, Strotmeyer ES, Resnick HE, Sellmeyer DE, Feingold KR, Cauley JA, et al. Diabetes and risk of hospitalized fall injury among older adults. *Diabetes Care*.2013; **36**(12): 3985-3991. doi: 10.2337/dc13-0429. [PMID: 24130352].
8. Berry SD, Miller R. Falls: epidemiology, pathophysiology, and relationship to fracture. *Curr Osteoporos Rep*. 2008. **6**(4): 149-154. doi: 10.1007/s11914-008-0026-4. [PMID: 19032925].
9. Rubenstein LZ, Josephson KR. The epidemiology of falls and syncope. *Clin Geriatr Med*.2002; **18**(2): 141-158. doi: 10.1016/s0749-0690(02)00002-2. [PMID: 12180240].
10. 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.* 2005; **35**(1): 11-16. doi: 10.1093/ageing/afi215. [PMID: 16303775]
11. Dingwell J, Cusumano JP, Sternad D, Cavanagh.Slower speeds in patients with diabetic neuropathy lead to improved local dynamic stability of continuous overground walking. *J Biomech*. 2000; **33**(10): 1269-1277. doi: 10.1016/s0021-9290(00)00092-0. [PMID: 10899337].
12. Menz H.B,Lord SR, George RS, Fitzpatrick RC. Walking stability and sensorimotor function in older people with diabetic peripheral neuropathy. *Arch Phys Med Rehabil*. 2004; **85**(2): 245-252. doi: 10.1016/j.apmr.2003.06.015. [PMID: 14966709]
13. Nardone A, Grasso M, Schieppati M. Balance control in peripheral neuropathy: are patients equally unstable under static and dynamic conditions? *Gait Posture.* 2006; **23**(3): 364-373.doi: 10.1016/j.gaitpost.2005.04.002. [PMID: 15896962]
14. Bruce D, Hunter M, Peters K, Davis T, Davis W., Fear of falling is common in patients with type 2 diabetes and is associated with increased risk of falls. *Age Ageing*, 2015; **44**(4): 687-690. doi: 10.1093/ageing/afv024. [PMID: 25739747]
15. De Mettelinge TR, Cambier D, Calders P, Den Noortgate NV, Delbaere K. Understanding the relationship between type 2 diabetes mellitus and falls in older adults: a prospective cohort study. *PloS One*. 2013; **8**(6): e67055. doi: 10.1371/journal.pone.0067055. [PMID: 23825617].
16. Zijlstra GA, Haastregt JCMV, Ambergen T, Rossum EV et al. Effects of a Multicomponent Cognitive Behavioral Group Intervention on Fear of Falling and Activity Avoidance in Community-Dwelling Older Adults: Results of a Randomized Controlled Trial.*J Am Geriatr Soc*. 2009;**57**(11): 2020-2028. doi: 10.1111/j.1532-5415.2009.02489.x.
17. Wong SL, Demers M, Martinod K, Gallant M, Wang Y, Goldfine AB, et al., Diabetes primes neutrophils to undergo NETosis, which impairs wound healing. Nature medicine, 2015; **21**(7): 815-819. doi: 10.1038/nm.3887. [PMID: 26076037]
18. Akbari M, Jafari H, Moshashaee A, Forugh B., Do diabetic neuropathy patients benefit from balance training?. *J Rehabil Res Dev.* 2012;**49**(2): 333.-8. doi: 10.1682/jrrd.2010.10.0197. [PMID: 22773533].
19. Yamamoto R, Kinoshita T, Momoki T, Arai T, Okamura A, Hirao K, et al. Postural sway and diabetic peripheral neuropathy. *Diabetes Res Clin Pract.* 2001; **52**(3): 213-221. doi: 10.1016/s0168-8227(01)00236-4. [PMID: 11323091].
20. Shaffer SW,. Harrison AL.Aging of the somatosensory system: a translational perspective. *Phys Ther*. 2007; **87**(2): 193-207. doi: 10.2522/ptj.20060083. [PMID: 17244695]
21. Boucher P, Teasdale N, Courtemanche R, Bard C, Fleury M . Postural stability in diabetic polyneuropathy. *Diabetes Care*. 1995; **18**(5): 638-645. doi: 10.2337/diacare.18.5.638. [PMID: 8586001]
22. Simmons RW, Richardson C, Pozos R. Postural stability of diabetic patients with and without cutaneous sensory deficit in the foot. *Diabetes Res Clin Pract*. 1997; **36**(3): 153-160. doi: 10.1016/s0168-8227(97)00044-2. [PMID: 9237781].
23. Corriveau H, Prince F, Hébert R, Raîche M, Tessier D, Maheux P, et al., Evaluation of postural stability in elderly with diabetic neuropathy. *Diabetes Care.* 2000;**23**(8): 1187-1191. doi: 10.2337/diacare.23.8.1187. [PMID: 10937520]
24. Ghanavati T, Shaterzadeh Yazdi MJ, Goharpey S, Arastoo AA. Functional balance in elderly with diabetic neuropathy. *Diabetes Res Clin Pract*. 2012;**96**(1): 24-28. doi: 10.1016/j.diabres.2011.10.041. [PMID: 22129655].
25. Simoneau GG, Ulberecht JS, Derr JA, Becker MB, Cavanagh PR. Postural instability in patients with diabetic sensory neuropathy. *Diabetes care*. 1994;**17**(12): 1411-1421. doi: 10.2337/diacare.17.12.1411. [PMID: 7882810].
26. Emam AA,Gad AM, Ahmed AM, Assal HS, Mousa SG. Quantitative assessment of posture stability using computerised dynamic posturography in type 2 diabetic patients with neuropathy and its relation to glycaemic control. *Singapore Med J.* 2009;**50**(6): 614-8.[PMID: 19551316].
27. Kukidome D, Nishikawa T, Sato M, Nishi Y, Shimamaura R, Kawashima J,et al. Impaired balance is related to the progression of diabetic complications in both young and older adults. *J Diabetes Complications.* 2017;**31**(8): 1275-1282. doi: 10.1016/j.jdiacomp.2017.05.014. [PMID: 28610947].
28. Toosizadeh N, Mohler J, Armstrong DG, Talal TK, Najafi B. The Influence of Diabetic Peripheral Neuropathy on Local Postural Muscle and Central Sensory Feedback Balance Control. *PLoS One*. 2015;**10**(8): e0135255. doi: 10.1371/journal.pone.0135255. [PMID: 26258497].
29. Timar B, Timar R, Gaiţă L, Oancea C, Levai C. The impact of diabetic neuropathy on balance and on the risk of falls in patients with type 2 diabetes mellitus: a cross-sectional study. *PloS One*. 2016;**11**(4): e0154654. doi: 10.1371/journal.pone.0154654. [PMID: 27119372].
30. Kluding PM, Pasnoor M, Singh R, Jernigan S, Farmer K, Rucker J, et al. The effect of exercise on neuropathic symptoms, nerve function, and cutaneous innervation in people with diabetic peripheral neuropathy. *J Diabetes Complications*. 2012;**26**(5): 424-429. doi: 10.1016/j.jdiacomp.2012.05.007. [PMID: 22717465].
31. Londhe A, Ferzandi Z. Comparison of balance and resistive exercises versus balance exercises alone in patients with diabetic peripheral neuropathy. *Indian J Physiother. Occup. Therapy*. 2012;**44**(2).
32. Bansal V, Kalita J, Misra UK. Diabetic neuropathy. *Postgrad Med J.* 2006;**82**(964): 95-100. doi: 10.1136/pgmj.2005.036137.
33. Perkins BA, Olaleye D, Zinman B, Bril V. Simple screening tests for peripheral neuropathy in the diabetes clinic. *Diabetes Care*. 2001;**24**(2): 250-256. doi: 10.2337/diacare.24.2.250. [PMID: 11213874].
34. Ponirakis G,Odriozola MN, Odriozola S, Petropoulos IN, Azmi S, Ferdousi M et al., NerveCheck for the detection of sensory loss and neuropathic pain in diabetes. *Diabetes Technol Ther.* 2016;**18**(12): 800-805. doi: 10.1089/dia.2016.0279. [PMID: 27922760].
35. Tesfaye S, Boulton AJM, Dyck PJ, Freeman R, Horowitz M, Kempler P, et al. Diabetic neuropathies: update on definitions, diagnostic criteria, estimation of severity, and treatments. *Diabetes Car.*2010; **33**(10): 2285-2293. doi: 10.2337/dc10-1303. [PMID: 20876709].
36. Young M, Boulton AJ, MacLeod AF, Williama DR, A multicentre

study of the prevalence of diabetic peripheral neuropathy in the United Kingdom hospital clinic population. *Diabetologia*. 1993; **36**(2): 150-154. doi: 10.1007/BF00400697. [PMID: 8458529].
37. Horak FB, Wrisley DM, Frank J. The balance evaluation systems test (BESTest) to differentiate balance deficits. *PhyTher*. 2009;. **89**(5): 484-498. doi: 10.2522/ptj.20080071. [PMID: 19329772].
38. Balducci S, Iacobellis G, Parisi L, Biase ND, Calandriello E, Leontti F,et al. Exercise training can modify the natural history of diabetic peripheral neuropathy.*J Diabetes Compliacations*. 2006;**20**(4): 216-223. doi: 10.1016/j.jdiacomp.2005.07.005. [PMID: 16798472].
39. Dixit S, Maiya AG, Shastry 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): 332-339. doi: 10.1016/j.jdiacomp.2013.12.006.
40. Loprinzi PD, Hager KK, Ramulu PY, Physical activity, glycemic control, and diabetic peripheral neuropathy: a national sample. *J Diabetes Complicat*. 2014;**28**(1): 17-21. doi: 10.1016/j.jdiacomp.2013.08.008. [PMID: 24090951].
41. Morrison S. Colberg SR, Parson HK, Vinik AI. Exercise improves gait, reaction time and postural stability in older adults with type 2 diabetes and neuropathy. *J Diabetes Complicat*. 2014;**28**(5): 715-722. doi: 10.1016/j.jdiacomp.2014.04.007. [PMID: 24929798].
42. Asif M. Batool S.Association between diabetic neuropathy, fall risks and balance in diabetes type 2 patients. *Rawal Med J*. 2020; **45**(1): 27-30.
43. Baharlouei H. Nodehi-Moghaddam A Correlation between Body Mass Index and Postural Balance in Elderly. *Arch Phys Med Rehabil*. 2012. **12**(0): 54-59.
44. Tilling LM. Darawil k, Britton M. Falls as a complication of diabetes mellitus in older people. *J diabetes complications*. 2006;**20**(3): 158-162. doi: 10.1016/j.jdiacomp.2005.06.004. [PMID: 16632235].
45. Miller DK, Lui LY, Prry HM, Kaiser FE, Morley JE. Reported and measured physical functioning in older inner-city diabetic African Americans. *J Gerontol A Biol Sci Med Sci*. 1999;**54**(5): M230-236. doi: 10.1093/gerona/54.5.m230. [PMID: 10362005]
46. Schwartz AV, Vittinghoff E, Sellmeyer DE, Feingold KR, Rekeneire ND, Stromeyer ES, et al. Diabetes-related complications, glycemic control, and falls in older adults. *Diabetes Care*. 2008;**31**(3): 391-396. doi: 10.2337/dc07-1152. [PMID: 18056893]..