PLANTAR SENSATION AND BALANCE IN PATIENTS WITH TYPE 2 DIABETES MELLITUS WITH AND WITHOUT PERIPHERAL NEUROPATHY

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SUMMARY – The aim of the study was to investigate the effect of diabetes on plantar sense and balance in patients with type 2 diabetes mellitus (T2DM). The study included 300 subjects divided into three groups: 100 T2DM patients with diabetic peripheral neuropathy (group 1); 100 T2DM patients without peripheral neuropathy (group 2); and 100 subjects without DM (group 3). Berg Balance Scale (BBS), Timed Up and Go test (TUG), single leg test with eyes open and closed, and plantar sensory tests were applied in the subjects. Study results showed significant differences in plantar sensory tests, BBS, TUG and single leg test among the three groups (p<0.05). In addition, duration of DM and medication were negatively correlated with single leg test both with eyes open and closed, but showed positive correlation with plantar sense and TUG test. Furthermore, the length of insulin therapy showed positive correlation with plantar sense and TUG test and negative correlation with BBS (p<0.05). In conclusion, DM has an effect on plantar sense and balance, and there is a relation between the duration of DM and balance problems. Balance problems are observed more often in patients with neuropathy.

Key words: *Balance; Diabetes mellitus; Plantar sense; Diabetic neuropathy; Semmes-Weinstein monofilaments*

Introduction

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disease damaging carbohydrate, fat and protein metabolism due to the absence of insulin secretion or decrease in insulin sensitivity of tissues, requiring continuous medical care[1,2]. Peripheral diabetic neuropathy (PDN) is one of the most common complications of diabetes characterized by a wide spectrum of problems, ranging from autonomous cardiovascular changes to diabetic foot ulcer, which decrease the pa-

tient quality of life[3-5]. In addition, in individuals with peripheral neuropathy, significant disorders of tactile sense, vibration, lower extremity proprioception and kinesthesia sense can be observed[6]. Plantar surface cutaneous sense is a highly significant sensory source in terms of ensuring static and dynamic balance control[7]. Particularly, static and dynamic test performances of individuals who have sensitivity disorder in plantar region, i.e. sensory function problems, are highly poor[8,9]. Since T2DM is a chronic disease that may damage body balance, it may cause deterioration of lower extremity function performance, falls and decrease in the quality of life[2,10-12]. This situation results in balance and fall problems. In individuals with systemic diseases such as DM, studies have demonstrated a relation be-

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tween changed plantar sense and balance[13-15]. The aim of this study was to investigate differences in plantar sensory and functional capacity, balance and relationship with diabetes among the groups of T2DM patients with and without PDN and volunteers without T2DM.

Subjects and Methods

Study design

Study design and study population were approved by the Abant İzzet Baysal University Ethics Committee (protocol number 2011-55). Each individual was given information on the method and objective of the study and patient approval form was signed by patients. As a result of the power analysis performed before the study, it was concluded that a total of 225 individuals should be included in the study, i.e. at least 75 individuals *per* group. Individuals with and without PDN who were diagnosed with DM and followed up at neurology and internal medicine outpatient clinics were informed about the study and invited to participate in the study. Control group of volunteers without DM was formed to match physical characteristics of individuals with DM. Volunteer group included those who agreed to participate in the study and met the criteria for participation in the study. Patients diagnosed with T2DM by specialist physicians in the Bolu Izzet Baysal State Hospital, Neurology and Internal Diseases Polyclinics, who were registered in diabetes polyclinics and followed-up by diabetes nurses on a regular basis, were included in the study. Thus, the study included 100 T2DM patients with mild-medium PDN diagnosed with electromyography (EMG) by a specialist physician (group 1); 100 T2DM patients without PDN (group 2); and 100 healthy subjects (group 3). Flow diagram in diabetes groups and control group is shown in Figure 1.

The criteria for inclusion in the study were as follows: age ≥30 years, being diagnosed with T2DM, good cognitive level, voluntary participation in the study, and absence of visual, hearing or speaking problems. Exclusion criteria were as follows: cognitive impairment, coronary failure, asthma and chronic obstructive pulmonary disease, plantar dermatologic disease, neurologic, rheumatic and musculoskeletal problems (leg edema, foot pathology, hip subluxation-

dislocation, lumbar disc herniation, lower extremity fractures, foot deformities, lower extremity contractures), taking medication for central nervous system problems, vestibular system problem, neuropathic diseases other than diabetic neuropathy (for example, hereditary motor-neuron sensory neuropathy), not being able to perform independent ambulation, having sustained lower extremity lesion or fracture in the last 6 months, and lower or upper extremity amputation at any level.

Demographic and clinical evaluation

In addition to the age, sex, weight and T2DM data, presence of any systemic disease, high cholesterol, HbA1c, fasting and postprandial blood glucose levels, time elapsed from the diagnosis of DM, and therapy with insulin or oral antidiabetic medicine were also recorded.

Instruments

Upon recording socio-demographic and clinical data on study subjects, the Time Up and Go Test (TUG), single leg test, Berg Balance Scale (BBS) and Semmes-Weinstein monofilament test (SWMT) were performed.

Functional mobility and balance

The BBS is a 14-item clinical scale evaluating static and dynamic balance abilities. Each item is rated from 0 (worst) to 4 (best). The highest possible score is 56, and scores of 45 and less indicate inability to ambulate independently and safely in daily life[16].

In the TUG, if the duration is longer, the mobility is considered to be poor[17]. Participants were timed in seconds, starting from the seated position, standing up, walking three meters, turning, walking back and sitting down again.

In the Single Leg Test, study subjects were required to start the test on one foot, without shoe, eyes open and arms close to the body. The time taken between the individual's lifting his/her foot and touching the ground again was recorded in seconds (s). Reaching maximum time of 60 s and individual's dislocating his/her foot were accepted as the time stop criterion. Each test was performed for both feet in turns[18].

The nylon Semmes-Weinstein monofilament test (SWMT), which is used to evaluate plantar sense in
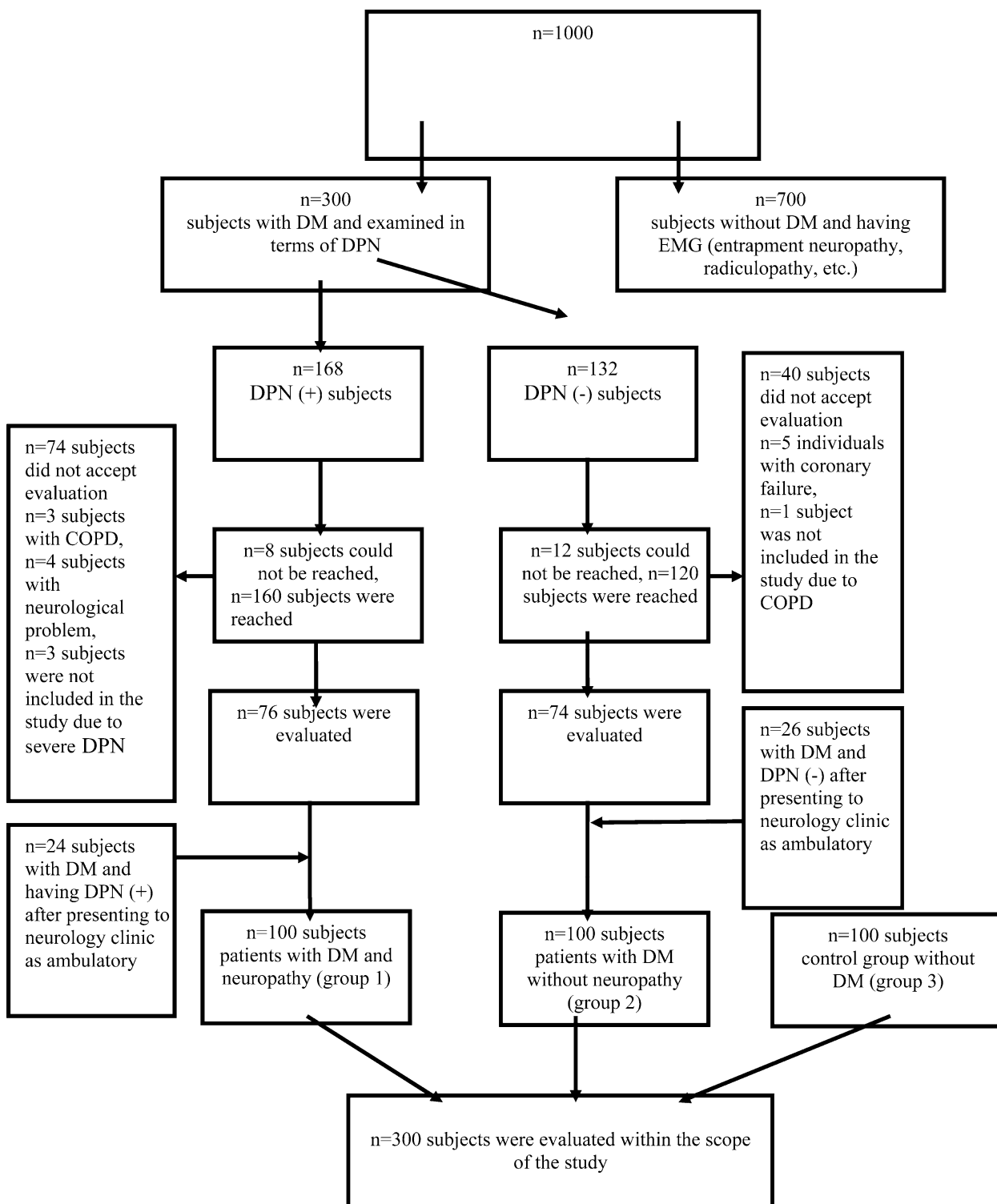
Fig. 1. Flow diagram of diabetes group and control group.

DM = diabetes mellitus; DPN = diabetic peripheral neuropathy; COPD = chronic obstructive pulmonary disease

Fig. 2. Plantar region: Semmes-Weinstein monofilament test.

individuals, is considered as a reliable method in diagnosing neuropathy. These monofilaments create pressure sensation by spreading bending stress over the skin and are identified with numbers from 1.65 to 6.65. The highest monofilament value is of the strongest and hardest bendable filament. Three monofilaments that are commonly used in patients with diabetic neuropathy are 4.17, 5.07 and 6.10 monofilaments[19-21]. When used in our study, subjects were asked to lie on the back and close their eyes, and they were barefoot. By standing at the foot side, the researcher physiotherapist touched the monofilament with 90-degree angle for 1.5 s in 7 regions (7 different regions consisting of the thumb, fifth toe, first and fifth metatarsal head, heel, medial and lateral side of the foot) on the weight-bearing plantar surface which was vulnerable to ulceration, and the subject was asked whether he/she felt it or not. This application was repeated in all regions of both feet by each of the three monofilaments (Fig. 2).

Statistical analysis

The results obtained were expressed as frequencies, mean ± standard deviation ($\chi\pm SD$), numbers (n) and percentage (%). The χ^2 analysis was used for relations among the groups and for categorically structured features. One-way analysis of variance was used to compare the groups according to quantitative features, and post-hoc Tukey test was used to determine differences among the groups. On determining differences among the groups, Bonferroni corrected z test relations between quantitative measurements were examined by Pearson correlation analysis. The level of statistical significance was set at p<0.05. Statistical analyses were performed using the SPSS ver. 18 software.

Results

There was no difference between the two patient groups according to the mean values of BMI and length of insulin therapy (p>0.05), however, statistically significant between-group differences were found in the mean values of weight, height, fasting glucose, postprandial glucose, HbA1c, DM duration and length of oral antidiabetic medicine therapy, yielding higher values in group 1 (p<0.05) (Table 1).

Statistically significant differences among the three groups were found in the left and right single leg test with eyes open and closed (p<0.05) (Table 2). The left and right single leg test with eyes open and closed, as well as BBS and TUG score differed statistically significantly between group 1 (T2DM patients with peripheral neuropathy) and the other two groups (p<0.05).

On two-group comparisons and between examinations performed in T2DM patients without neuropathy and healthy subjects, statistically significant differences were recorded in the left and right single leg test with eyes open, TUG and BBS test scores (p<0.05). Examinations performed in T2DM patients without neuropathy and healthy control subjects yielded no differences in the left and right single leg test with eyes closed scores (p>0.05).

Regarding the monofilaments used in three different thicknesses, statistically significant differences were found among the groups in plantar regions 1, 2, 3, 4, 5, 6, and 7 on the left and right feet (p<0.05) (Figs. 3 and 4). T2DM patients with neuropathy could perceive higher filament thickness compared to healthy control subjects. In addition, perception of T2DM patients without neuropathy was found to be worse compared to healthy subjects, which held true for all right and left foot plantar senses.

On correlation analysis performed with evaluation parameters in 200 DM patients, a correlation was found between HbA1c and right foot plantar regions 1, 2, 3, 4, 5, 6, 7 and left foot plantar regions 1, 2, 3, 4, 5, 6 (p<0.05), between diabetes duration and all plantar sense regions in the right and left feet, left and

Table 1. Socio-demographic and clinical features of study subjects

	Group 1 (n=100)		Group 2 (n=100)		Group 3 (n=100)		F, χ^2	p
	$\chi\pm SD$	Median	$\chi\pm SD$	Median	$\chi\pm SD$	Median		
Age (yrs)	61.54±8.59	63	59.82±8.19	59	59.72±10.04	59	1.29	0.27
Height (cm)	1.65±0.82	1.65	1.62±0.70	1.63	1.63±0.67	1.63	3.12	0.04*
Weight (kg)	83.01±13.57	80	79.18±11.41	80	77.29±11.65	75.5	5.65	0.00*
BMI (kg/m^2)	3.34±4.57	29.54	29.91±4.71	29.49	28.91±4.10	28.56	2.68	0.07
Fasting glucose (mg/dL)	172.73±57.90	161.50	136.04±41.14	125.00	-	-	25.24	0.00*
Postprandial glucose (mg/dL)	243.70±94.84	225.00	182.46±69.03	170.00	-	-	23.01	0.00*
HbA1c (%)	8.31±1.75	7.4	6.42±1.20	6.5	-	-	28.45	0.00*
Diabetes (yrs)	12.35±7.59	4	7.69±6.54	3	-	-	21.60	0.00*
Insulin (yrs)	4.54±5	3	4.51±5.19	2	-	-	0.00	0.97
OAD (yrs)	11.54±6.83	10	7.04±6.32	5	-	-	21.77	0.00*
Systemic disease, n (%)	65 (65)		61 (61)		38 (38)		21.34	0.00*
Cholesterol, n (%)	40 (40)		34 (34)		18 (18)		12.16	0.00*

*p<0.05; F = analysis of variance (ANOVA); BMI = body mass index; OAD = oral antidiabetic drugs; χ^2 = chi square; group 1 = diabetic peripheral neuropathy; group 2 = without peripheral neuropathy; group 3 = control group

Table 2. Results of single foot test with eyes open and closed according to groups

		Group 1 (n=100)		Group 2 (n=100)		Group 3 (n=100)		F	p
		$\chi\pm SD$	Median	$\chi\pm SD$	Median	$\chi\pm SD$	Median		
Eyes open (s)	Right foot	13.27±14.10	8.50	22.70±19.04	15	29.50±18.98	28	21.619	0.00*
	Left foot	11.61±12.28	8	21.52±19.12	14	28.65±18.48	25.5	25.590	0.00*
Eyes closed (s)	Right foot	2.32±2.90	2	5.20±5.94	3	6.55±5.69	5	18.368	0.00*
	Left foot	2.17±2.62	2	4.96±6.50	2	5.90±4.95	5	15.297	0.00*
	TUG	8.44±1.66	8.26	7.39±1.20	7.20	6.69±1.20	6.61	40.881	0.00*
	BBS	50.22±3.13	50.00	52.25±3.21	52.00	53.87±2.67	55.00	36.774	0.00*

*p<0.05; F = analysis of variance (ANOVA); TUG = Timed Up and Go Test; BBS = Berg Balance Scale; s: seconds

right single leg test with eyes open, left and right single leg test with eyes closed, TUG and BSS (p<0.05), and between the length of oral antidiabetic therapy and right plantar regions 1, 2, 3, 4, 5, 6, left plantar regions 2, 4, 6, left and right single leg test with eyes open, left and right single leg test with eyes closed, TUG and BSS (p<0.05), and between insulin use and left foot plantar region 1, TUG and BSS (p<0.05) (Table 3).

Discussion

The results of our study showed that there was a difference in the levels of plantar sense perception, and static and dynamic balance values between healthy subjects and T2DM patients. It was also found that diabetes had an effect on plantar sense and balance, and there was a correlation between duration of diabetes and balance problems. In addition, we also found that balance problems were more pronounced in T2DM patients with diabetic neuropathy.

Plantar cutaneous sense is a highly significant sensory source in terms of ensuring static and dynamic balance control[10]. According to the literature, it is known that using SWMT in patients with diabetic neuropathy provides quite reliable data[19,21-24]. In addition, there are many studies emphasizing that
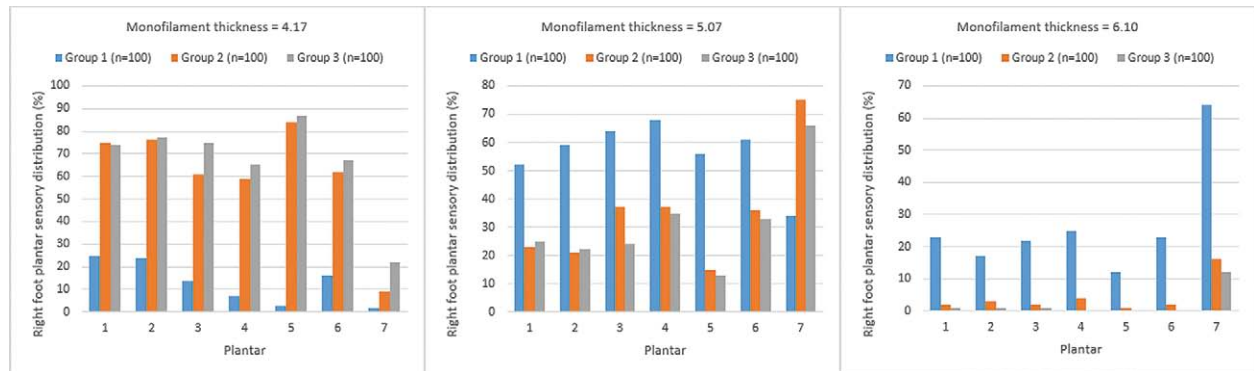
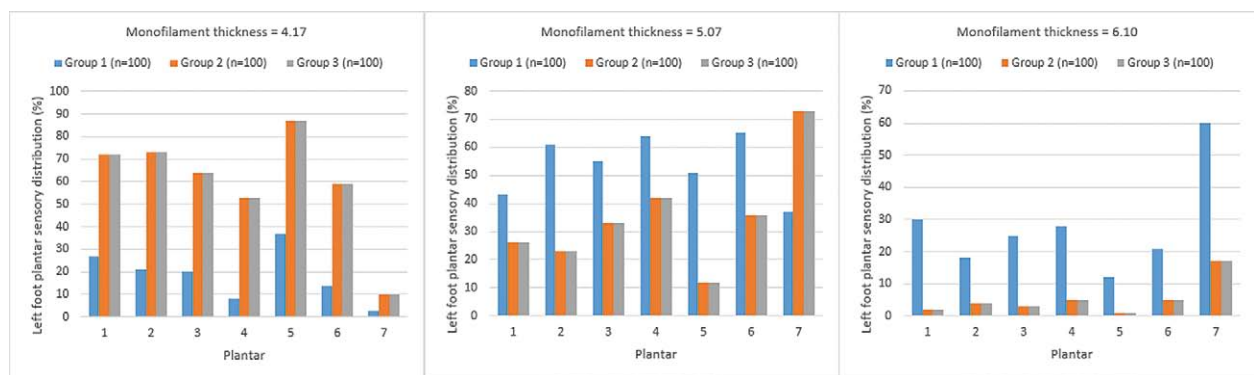*Fig. 3. Right foot plantar sensory distribution.*

Fig. 4. Left foot plantar sensory distribution.

5.07-thick evaluations are a good determinant in patients with diabetic neuropathy[10,20].

In the study by Kamei *et al.* conducted for the purpose of determining the effect of SWMTs on measuring plantar sense in patients with diabetic peripheral neuropathy, SWMT 5.07-thick evaluations were found to be associated with lower extremity vibration perceiving threshold, ankle reflex and knee reflex. Goddard *et al.* report on the SWMT obtained over toe, plantar surface of the first metatarsus and plantar surface of the fifth metatarsus in patients with diabetes to be most effective, without difference between the right and left feet, suggesting that this combination of measurements is more effective if used together[25,26].

In our study, SWMT was used in three different thicknesses, i.e. 4.17 (1.4 g), 5.07 (10 g), and 6.10 (100 g). The results obtained with three different monofilaments used in SWMT measurements showed significant differences in all regions on the right and left feet among the groups. It was found that patients with

T2DM and neuropathy perceived thicker filaments (5.07, 6.10) compared to T2DM patients without neuropathy and healthy control group. T2DM patients without neuropathy could feel thicker filaments compared to healthy control group, indicating a decrease in plantar cutaneous sense compared to healthy individuals although neuropathy had not developed. Pery examined the level of plantar sense receptivity in elderly and young adults and found that decrease in plantar surface cutaneous sense together with advancing age caused balance problems[7]. Mold *et al.* conducted a study in the elderly with peripheral sensory neuropathy and showed that 71% of the patients had only one of the position, tactile and vibration sense deficit, 22% had two deficits, 7% had three deficits, and 1% had four deficits; they also report that the observed pain level, balance and walking problems, and fall frequency increased considerably in the last 3 months as the sense deficit problem increased[27]. Bokan Mirković *et al.* report on the lack of protective sensitivity of the foot as a major risk factor for falls[28].

Table 3. Relation between HbA1c, diabetes duration, length of oral antidiabetic use, length of insulin use and plantar sense in patients with diabetes

	Feature n=200	HbA1c		Diabetes duration		OAD		Insulin	
		r	p	r	p	r	p	r	p
Right foot plantar zone	Zone 1	0.45**	0.00	0.29**	0.00	0.24**	0.00	0.17	0.07
	Zone 2	0.50**	0.00	0.22**	0.00	0.16*	0.02	0.00	0.94
	Zone 3	0.44**	0.00	0.21**	0.00	0.15*	0.03	0.16	0.08
	Zone 4	0.56**	0.00	0.26**	0.00	0.19**	0.00	0.03	0.71
	Zone 5	0.34**	0.00	0.21**	0.00	0.15*	0.03	0.09	0.31
	Zone 6	0.34**	0.00	0.26**	0.00	0.22**	0.00	0.03	0.71
	Zone 7	0.35**	0.00	0.22**	0.00	0.13	0.07	0.18	0.06
Left foot plantar zone	Zone 1	0.39**	0.01	0.19**	0.00	0.13	0.06	0.22*	0.00
	Zone 2	0.28*	0.01	0.21**	0.00	0.18*	0.01	0.05	0.59
	Zone 3	0.43**	0.00	0.20**	0.00	0.12	0.08	0.11	0.26
	Zone 4	0.36**	0.00	0.23**	0.00	0.19**	0.00	0.13	0.17
	Zone 5	0.31**	0.00	0.17*	0.01	0.06	0.34	0.02	0.78
	Zone 6	0.37**	0.00	0.24**	0.00	0.15*	0.03	0.11	0.24
	Zone 7	0.20	0.09	0.19**	0.00	0.09	0.22	0.15	0.11
SLS	R_{EO}	-0.04	0.69	-0.24**	0.00	-0.23**	0.00	-0.16	0.09
	L_{EO}	-0.06	0.58	-0.23**	0.00	-0.20**	0.00	-0.17	0.07
	R_{EC}	-0.08	0.49	-0.24**	0.00	-0.23**	0.00	-0.15	0.11
	L_{EC}	-0.11	0.35	-0.21**	0.00	-0.20**	0.00	-0.17	0.06
	TUG	0.00	0.95	0.25**	0.00	0.22**	0.00	0.24*	0.01
	BBS	-0.06	0.62	-0.27**	0.00	-0.24**	0.00	-0.26**	0.00

**p<0.01; *p<0.05; r = correlation coefficient; HbA1c = hemoglobin A1c; TUG = Time Up and Go Test; SLS = single leg stance, R_{EO} = right single leg stance with eyes open; L_{EO} = left single leg stance with eyes open; R_{EC} = right single leg stance with eyes closed; L_{EC} = left single leg stance with eyes closed; BBS = Berg Balance Scale; OAD = oral antidiabetic drugs

Our findings were consistent with those reported in the abovementioned studies. The average age of the subjects included in the study was at the geriatric borderline, median range 59-63 years. We think that balance problems experienced by the subjects might have been affected by age, as well as by diabetes.

Cimbiz and Cakir compared patients diagnosed with diabetes and neuropathy for 8.6±5.6 years with control group and found the results of static and dynamic unipedal stance test to be lower in patients with diabetic neuropathy[2]. In their study, de Oliveira *et al.* found no statistically significant between-group difference in the number of falls when compared diabetic patients and healthy control group; however, TUG values were better in non-diabetic subjects and there was a correlation between hyperglycemic status and poorer mobility. However, it was stated that this relation resulted in an increased risk of falls in younger patients and even in those with a shorter duration of disease[29].

Cordeiro *et al.* report that the mean test time was 15.7±6.5 s, and most patients (67.8%) took between 10-20 s, and 21.1% of patients took more than 20 s to complete the test. However, only women were involved in this study, mean age 74.4±5.9 years[10].

In another study conducted by Alvarenga *et al.*, TUG period was longer (10.46 *vs.* 8.95 s, p<0.01) compared to control group[30]. Hamada and El Debrky compared motor function and postural sways of DM patients and healthy individuals; their results showed that the speed of forward progression of patients with DM was lower, while the response latency and end point sway velocities were higher in DM patients compared to healthy individuals. This information was significant in terms of avoiding the risk of falls[31]. Similarly, Wuehr *et al.* found that the variables of gait ve-

locity, step length, amplitude of ankle movement, ankle moments of force, power and anterior-posterior ground reaction force were lower in patients with DM and diabetic polyneuropathy compared to their healthy peers[32]. In our study, the values of balance and timed performance were lower and the risk of falls was higher in T2DM patients compared to healthy individuals, which is consistent with the studies mentioned above.

In our study, TUG values were highest in group 1 with neuropathy (8.44±1.66 s) and lowest in healthy individuals (6.69±1.20 s). These values were lower than those in the studies by Cordeiro *et al.*[10] and Alvarenga *et al.*[30] because the mean age of the individuals in our study was lower than the mean age of the individuals in those two studies. While the median age range in our study was 59-63 years for the three groups, the mean age was 74.4±5.9 years in the study by Cordeiro *et al.*[10] and 70-79 years in the study by Alvarenga *et al.*[30]. This shortage in TUG values of patients with DM in our study compared to other studies was attributed to the age factor. When the risk factors of diabetes are concerned, there are studies indicating that HbA1c values affect postural control; however, there also are studies stating that there is no such relationship. Bardawil *et al.* found that HbA1c had no relation with any of the dynamic posturography variables[33]. However, in the study by Schwartz *et al.*, low HbA1c value in patients using insulin was associated with a low risk of fall, which increased with increase in the HbA1c value. It was also reported that low HbA1c in individuals using hypoglycemic medicines (but not insulin) was not associated with the risk of fall. In the same study, disease duration was 12.8±12.4 years, and standing balance time, chair stands, 6-m walk and knee extensor muscular force values were associated with falls[34]. In our study, duration of diabetes was 12.35±7.59 years in patients with neuropathy and 7.69±6.54 years in patients without neuropathy; there was a relationship between the monofilament test values used in evaluating diabetes duration and plantar sense. Likewise, a relation was detected between HbA1c values and plantar sense monofilament values. Contrary to the study by Schwartz *et al.*[34], there was a correlation of the length of using oral antidiabetic medication with the balance and timed performance test values (BBS and TUG) in patients using oral antidiabetics, as well as in those using insulin. A correlation was detected between the length of using oral

antidiabetic medicine (but not the length of insulin use) and the period of standing on one foot. While the mean length of oral antidiabetic medicine use in our study was 11.54±6.83 years (median 10 years), the length of insulin use was lower (mean 7.04±6.32 years, median 5 years). Results of our study showed that HbA1c value affected plantar sense, diabetes period, length of using oral antidiabetic medicine and insulin use, and these were associated with balance and timed performance (mobility). These results show that precautions should be taken in order to minimize the side effects caused by long-term medical treatment in patients with DM, and patients should be evaluated by specialist medical personnel to collect information on balance problems and risk of fall from the early period.

Loss of plantar sense in patients is a vital factor causing balance and mobility problems, and particularly, it deteriorates with duration of the disease in patients with neuropathy, as well as in those without neuropathy.

A limitation of our study was the lack of proprioception assessment of ankle and foot. The strengths of our study was EMG usage as an objective method to identify PDN and comparison of three groups consisting of diabetic patients with and without PDN, and age-matched volunteer individuals without diabetes.

Conclusion

At the end of the study, it was concluded that T2DM patients with and without neuropathy experienced balance, sense and mobility losses when compared to healthy control subjects. Significant differences were recorded in patients with neuropathy and longer duration of diabetes and excessive use of medicine, as well as in those without neuropathy. We believe that early and practical measures (such as diet, physical activity counseling, lifestyle modification, etc.) can be useful in detecting neuropathy and preventing complications.

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Sažetak

OSJETILNOST TABANA I RAVNOTEŽA U BOLESNIKA SA ŠEĆERNOM BOLEŠĆU TIP 2
S PERIFERNOM NEUROPATIJOM I BEZ NJE

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Cilj istraživanja bio je ispitati učinak šećerne bolesti na osjetilnost tabana i ravnotežu u bolesnika sa šećernom bolešću tip 2 (T2DM). U istraživanje je bilo uključeno 300 ispitanika podijeljenih u tri skupine: 100 bolesnika s T2DM i dijabetičkom perifernom neuropatijom (1. skupina), 100 bolesnika s T2DM bez dijabetičke neuropatije (2. skupina) i 100 ispitanika bez DM (3. skupina). Kod svih ispitanika primijenjeni su sljedeći testovi: *Berg Balance Scale* (BBS), *Timed Up and Go test* (TUG), test ravnoteže na jednoj nozi s otvorenim i zatvorenim očima te testovi osjetilnosti tabana. Rezultati su pokazali značajne razlike u testovima osjetilnosti tabana, BBS, TUG i testu ravnoteže na jednoj nozi među trima skupinama (p<0,05). Uz to, trajanje DM i primjene lijekova negativno je koreliralo s testom ravnoteže na jednoj nozi s otvorenim i zatvorenim očima, ali je pokazalo pozitivnu korelaciju s osjetilnošću tabana i testom TUG. Nadalje, trajanje inzulinske terapije pokazalo je pozitivnu korelaciju s osjetilnošću tabana i testom TUG te negativnu korelaciju s BBS (p<0,05). U zaključku, DM utječe na osjetilnost tabana i ravnotežu te postoji povezanost trajanja DM i problema s ravnotežom, koji su češći u bolesnika s neuropatijom.

Ključne riječi: *Ravnoteža; Šećerna bolest; Osjetilnost tabana; Dijabetička neuropatija; Semmes–Weinsteinovi monofilamenti*