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Postural control in patients with type 2 diabetes with vertigo, dizziness and/or imbalance

Controle postural em indivíduos com diabetes *mellitus* do tipo 2 com vertigem, tontura e/ou desequilíbrio

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ABSTRACT

Purpose: To evaluate postural control in diabetes mellitus Type 2 patients (T2DM) with vertigo, dizziness and/or imbalance. **Methods:** T2DM patients, 15 females and five males, ranging from 46 to 83 years old, and a control group of 20 healthy individuals with no complaints paired according to age and gender were submitted to the Brazilian version of the Dizziness Handicap Inventory (DHI), dizziness analog scale, and the *Tetrax IBS*™ static posturography in eight sensory conditions. **Results:** The experimental group had moderate impairment in quality of life according to the DHI (mean of 31.30 points) and a mean score of 6.45 points in the dizziness analog scale. There was a significant difference between the groups in all or some sensory conditions concerning the values of the general stability index, frequency bands of postural oscillation, postural oscillation synchronization indexes, and the risk of falling. **Conclusion:** T2DM patients with vertigo, dizziness and/or imbalance may present postural control impairment in posturography, characterized by changes in general stability, postural oscillation synchronization, frequency ranges of postural oscillation and risk of fall, suggesting vestibular, visual and somatosensory dysfunction or in their interaction in the central nervous system.

Keywords: Postural balance; Vertigo; Dizziness; Diabetes mellitus type 2; Vestibular function tests

RESUMO

Objetivo: avaliar o controle postural em indivíduos com diabetes *mellitus* do tipo 2 (DM2) com vertigem, tontura e/ou desequilíbrio à posturografia. **Métodos:** pacientes com DM2, 15 do sexo feminino e cinco do masculino, idades entre 46 e 83 anos e um grupo controle de 20 indivíduos hígidos, pareados por idade e sexo, 15 do sexo feminino e cinco do masculino, idades entre 46 e 81 anos foram submetidos à versão brasileira do *Dizziness Handicap Inventory* (DHI) e escala visual analógica de vertigem ou tontura e posturografia estática do *Tetrax IBS*™, em oito condições sensoriais. **Resultados:** o grupo experimental apresentou prejuízo moderado na qualidade de vida ao DHI (média de 31,30 pontos) e pontuação média de 6,45 pontos na escala visual analógica de vertigem ou tontura. Houve diferença significativa entre os grupos, em todas ou algumas condições sensoriais, em relação aos valores do índice de estabilidade geral, das faixas de frequência de oscilação postural, dos índices de sincronização da oscilação postural e do índice de risco de queda. **Conclusão:** indivíduos com DM2 com vertigem, tontura e/ou desequilíbrio podem apresentar distúrbio do controle postural à posturografia, caracterizado por alterações da estabilidade geral, sincronização da oscilação postural, faixas de frequência de oscilação postural e risco de queda, sugerindo disfunção vestibular, visual e somatossensorial, ou em sua interação no sistema nervoso central.

Keywords: Equilíbrio postural; Vertigem; Tontura; Diabetes *mellitus* tipo 2; Testes de função vestibular

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INTRODUCTION

Diabetes *mellitus* (DM) is one of the major causes of mortality worldwide. Population growth and aging, physical inactivity, overweight, and inadequate eating habits predispose the population to the increased incidence and prevalence of DM[1].

DM comprises a heterogeneous group of metabolic disorders characterized by hyperglycemia due to inadequate insulin secretion and/or action. DM may be classified, into four clinical groups according to its etiology: type 1, type 2 (T2DM), gestational, and other specific types. Additionally, there are two other categories —impaired fasting blood glucose and impaired glucose tolerance, which are called as pre-diabetes and are not clinical entities in themselves, but risk factors for developing DM and cardiovascular diseases[1].

T2DM, identified in 90% to 95% of DM cases, is caused by an interaction between genetic and environmental factors. Its characteristics are dysfunctions in insulin action and secretion and regulation of liver glucose production; the pancreas does not produce enough insulin to maintain normal blood glucose levels, or the body is unable to use the insulin produced, resulting in insulin resistance. The condition can appear at any age, but it is generally diagnosed after 40[1].

The vestibular system is often affected in T2DM, which can become a complication associated with the condition due to the effects of chronic hyperglycemia[2] or to variations in blood glucose and insulinemia.

The precise mechanism and the location of the vestibular sensory epithelial lesion in diabetes are not fully known[3]. Although the physiopathology of vestibular sensory organ impairment in diabetic individuals is not clear, hyperglycemia may be related to the clinical signs of peripheral vestibulopathy, body balance problems, functional incapacitation, and falls[2,3]. Dysglycemic patients may suffer from hearing and vestibular symptoms, such as vertigo, floating sensation, hearing loss, tinnitus, aural fullness, discomfort with intense sounds, and weakness, sweating and diarrhea[4]. Postural imbalance and falls are very frequent in people with diabetes[2,5-7]. Disturbance in body balance is one of the factors usually identified as risks of falls in T2DM, which impair patients' quality of life, as it can result in reduced mobility and activity, and increased hospitalization and mortality[7].

The patient's static or dynamic body oscillation and postural performance can be evaluated quantitatively using a pressure-sensitive force platform[8]. The static posturography of the Tetrax Interactive Balance System (Tetrax IBS™, Sunlight Medical Ltd., Tel Aviv, Israel) with four plates, captures variations in weight distribution and compares the values from each foot's toes and heel with those of the collateral foot, analyzing postural balance and the mechanisms to maintain it[9]. Each plate has a tension gauge that transforms the variations in vertical forces into analogical wave electrical signals[9]. These data can be useful for clinical evaluation of body imbalance undiagnosed by other neurotological tests. The characterization of postural control disorders has important diagnostic and therapeutic implications, in addition to preventing falls[5].

The prevalence of T2DM rises increasingly. Its characteristics, complications and chronic nature impair patients' quality of life. The lack of studies quantifying and characterizing postural balance in T2DM and vestibular complaints using posturography, especially Tetrax IBS™, justify undertaking this survey. The parameters that distinguish Tetrax IBS™ from other posturographic devices may contribute to a broader knowledge of postural control and vestibular disorders in these patients, with potential diagnostic implications and consequences for therapeutic orientation.

The objective of this investigation was to evaluate postural control in patients with type 2 diabetes *mellitus* with vertigo, dizziness and/or imbalance using posturography.

METHOD

This is a controlled cross-sectional study undertaken within the Otology and Neurotology division [Disciplina de Otologia e Otoneurologia] of the Department of Otorhinolaryngology and Head and Neck Surgery of *Universidade Federal de São Paulo – Escola Paulista de Medicina* (UNIFESP-EPM), after approval of the Research Ethics Committee [*Comitê de Ética em Pesquisa*] – CEP UNIFESP, under nº 1.981.140. All individuals were informed of the procedures undertaken and signed a Free Informed Consent to allow their participation in the study and subsequent analysis and dissemination of results.

The experimental group had 20 patients with T2DM of both genders over 18 years old who reported vertigo, dizziness and/or imbalance—as the inclusion criteria—and were undergoing follow-up and treatment with antidiabetic medication and dietary guidance at the Endocrinology and Metabology Outpatient Clinic and Diabetes Center of the Endocrinology Department [Ambulatório de Endocrinologia e Metabologia e Centro de Diabetes da Disciplina de Endocrinologia] of UNIFESP-EPM.

The control group, paired by age and gender with the experimental group, had volunteers from the community without any history of metabolic or orthopedic disorders, hearing, vestibular or visual disorders, nor neurological complaints. A medical diagnosis of T2DM and vertigo, dizziness, and/or imbalance complaints was the inclusion criteria of the experimental group patients.

Patients who had diabetic polyneuropathy, retinopathy, kidney, liver or heart failure, neurological disorders; unable to understand and follow simple verbal commands, incapable of keeping the orthostatic position unaided; visual impairment uncompensated by corrective lenses, orthopedic disorders resulting in limitation of movement or used prostheses in the lower limbs; suffered from psychiatric disorders; had been using medication affecting the vestibular system; and had undertaken body balance rehabilitation in the six months before the study were excluded from the study.

Participants underwent a neurotological evaluation comprising anamnesis, otorhinolaryngological examination, the Brazilian version[10] of the Dizziness Handicap Inventory (DHI)[11], the visual analog scale of vertigo or dizziness[12] and static posturography using Tetrax IBS™ (Sunlight Medical Ltd., Tel Aviv, Israel)[9].

The quality of life questionnaire, the Brazilian DHI version, was applied to evaluate self-perception of the incapacity imposed by dizziness. This instrument, comprising twenty-five questions, evaluated three general domains: the physical, emotional, and functional, with seven, nine, and nine questions, respectively. The evaluator read the questionnaire to the patients, who were instructed to reply to each question only with "yes," "no," or "sometimes." Four points were awarded to each "yes" answer, 0 points to each "no," and 2 points to each "sometimes" answer. Thus, the higher the value, the more affected was their quality of life[11]. The total DHI score was rated as mild (0-30 points), moderate (31-60) or severe (61-100)[13].

The intensity of these symptoms was quantified in the visual analog scale of vertigo or dizziness. The individuals assigned a score (0 to 10) to the intensity of their dizziness at the time of evaluation, in which 0 indicated the lowest level of dizziness and 10, the highest[12]. The severity of symptoms was classified as either mild (0-3 points), moderate (4-6), or severe (7-10)[14].

Posturography using Tetrax IBS™ was undertaken in a quiet, semi-obscure room. The equipment included specific software installed on a computer, foam-rubber pillows, and a platform with handrail. The force platform comprised four independent and integrated plates (A-B-C-D), disposed on a leveled, uncarpeted floor. A target was positioned at eye level, one meter in front of the individual being evaluated. Before starting the evaluation and with the platform empty, the equipment was calibrated using the software installed on the computer.

The patients, barefoot, positioned their toes and heels over a guiding design with their arms stretched along with their bodies. The individuals were asked to keep silent and maintain an upright, stable and unmoving posture for 32 seconds, in each of the eight sensorial conditions evaluated[9]:

- NO (Normal Open) sensorial condition: patient-facing forward, eyes open, looking at a point on the wall opposite the platform, on a stable surface. This is a neutral posture in which the visual, somatosensory and vestibular systems are examined;
- NC (Normal Closed) sensorial condition: patient-facing forward, eyes closed, on a stable surface. In this position, visual information is eliminated, and the somatosensory and vestibular systems are tested;
- HR (Head Rightward) sensorial condition: the individual with eyes closed, head rotated 45° to the right, on a stable surface. This position eliminates sight and evaluates the vestibular system;
- HL (Head Leftward) sensorial condition: the individual with eyes closed, head rotated 45° to the left, on a stable surface. This position eliminates sight and evaluates the vestibular system;
- HB (Head Backward) sensorial condition: individual with eyes closed, head tilted 30° backward, on a stable surface. This position eliminates sight and evaluates the vestibular system and the cervical segment;
- HF (Head Forward) sensorial condition: individual with eyes closed, head tilted 30° forward, on a stable surface. This position eliminates sight and evaluates the vestibular system and the cervical segment;
- PO (Pads Eyes Open) sensorial condition: patient-facing forward, eyes open, looking at a point on the wall opposite the platform, on an unstable surface (standing on foam-rubber pillows). This position limits the effect of proprioception and evaluates the visual and vestibular systems;
- PC (Pads Eyes Closed) sensorial condition: patient-facing forward, eyes closed, on an unstable surface (standing on foam-rubber pillows). This position eliminates sight, limits the effect of proprioception and evaluates the vestibular system.

Tetrax IBS™ posturography measures variations of the vertical force exerted by the heels and feet tips, detecting body swaying by the displacement of the center of pressure. The computer program supplies values for the following parameters: stability index, weight distribution index, synchronization index, body sway frequencies in each of the eight sensorial conditions, and risk of falling[9].

The stability index shows the individual's global stability and his/her ability to compensate for postural changes. It measures the rate of sway on the four platforms; the higher the score, the greater the instability[9].

The weight distribution index compares weight distribution in each platform calculated based on the weight recorded on each of the four plates; the higher the score, the greater the difficulty in maintaining balance[9].

The sway synchronization index measures coordination between the lower limbs and the symmetry in weight distribution. For each condition, six synchronization measurements are done: between the heels and the toes of each foot (AB, CD), between both heels and the toes of both feet (AC, BD) and the two diagonals between the heel of each foot and the contralateral toes (AD, BC). High synchronization values can indicate postural stiffness or intentional simulations of lateral postural swaying; low values can point to desynchronization with likely alteration of the fine control mechanisms; values with inverted signs suggest excessive postural swaying[9].

Postural sway frequencies vary within a spectrum comprehended between 0.01 and 3.0 Hz, subdivided into four frequency ranges: low (F1), below 0.1 Hz; medium-low (F2-F4), between 0.1 – 0.5 Hz; medium-high (F5-F6), between 0.5 – 1.0 Hz; and high (F7-F8), above 1.0 Hz. Each Postural sway frequency range emphasizes the use of a particular postural subsystem: prevalence of postural sway in the low-frequency range suggests normal postural control and integrity of the vestibular, visual and somatosensory systems; in the low-medium range, peripheral vestibular dysfunction; in the medium-high range, somatosensory reactions mediated by the lower limb and spine motor system and, in the high range, central nervous system impairment[9].

The fall risk index weighs the results of the Tetrax IBS™ parameters in the eight conditions evaluated. It can vary between 0 and 100%; a value between 0 and 36% is considered low risk; between 37% and 58%, moderate risk; and between 59% and 100%, high risk[9].

We submitted the results to a descriptive statistical analysis for the characterization of the sample. We applied the Shapiro-Wilk test to verify the normality of the data. Student's t-test was used for age, and weight comparison between groups for independent samples and Pearson's chi-square test was used to analyze sex homogeneity. The student's t-test was used for independent samples (parametric) or the Mann-Whitney U (nonparametric) test for the stability index and body sway frequency ranges. Mann-Whitney's U test was used for synchronization indexes. The student's t test was used regarding the weight distribution index and fall risk index in independent samples. Data were presented as frequencies (relative and absolute), mean, standard deviation, median, and minimum and maximum values. A 5% significance level was adopted ($p<0.05$). IBM SPSS Statistics, version 23.0, and Office Excel 2015 were used for calculations.

RESULTS

Of the 155 individuals with T2DM approached at the UNIFESP-EPM Endocrinology and Metabology Outpatient Clinic and Diabetes Center of the Endocrinology Department, 105 did not complain of vertigo, dizziness and/or imbalance. Among the 50 patients with T2DM who presented vertigo, dizziness and/or imbalance, 25 were not included in the survey due to the exclusion criteria (eight had a history of central nervous system impairment, three had visual impairment interfering with visualization of stimuli, ten had orthopedic impairments, and four had kidney disorders), four did not want to take part in the survey, and one did not complete the posturographic evaluation because he/she was unable to maintain the positions with eyes closed and head tilted for the time needed for the test.

Forty individuals were evaluated, 20 of whom in the experimental group, comprised of T2DM patients with vertigo, dizziness and/or imbalance, and 20 in the control group. Table 1 presents the descriptive values and comparative analysis of the demographic data for the experimental and control groups, time with the disease and antidiabetic medication of the experimental group.

The average scores found in applying the Brazilian version of the DHI quality of life questionnaire in the experimental group were 31.30 ± 21.51 points (ranging between 6 and 90 points) for the total score, 11.7 ± 6.19 points for the physical domain, 8 ± 8.33 points for the emotional domain, and 11 ± 8.34 points for the functional domain. Thirteen individuals (65%) had a total DHI score classified as mild, six (30%) as moderate, and one (5%) as severe.

The score on vertigo and dizziness visual analog scale for the experimental group varied between 1 and 10, with an average of 6.45 ± 2.82 points. Eleven patients (55%) had a score classified as severe on the scale, five (25%) were classified as moderate, and four (20%) as mild.

The experimental group presented a higher general stability index than the control group in all conditions evaluated, with a significant difference (Figure1).

As for the weight distribution index, no difference was found between the groups in all conditions evaluated (Figure 2).

Regarding the synchronization index with eyes open on a stable surface (NO), the experimental group presented higher absolute values than the control group in the synchronization between left foot toes and right foot heel (BC), with significant difference (p = 0.043). In the condition of head tilted 30° backwards on a stable surface (HB), the experimental group presented lower absolute values than the control group in the synchronizations between left foot toes and heels (AB) (p=0,023) and right foot and left foot toes (BD) (p = 0.001), with significant difference. In the condition of open eyes on an unstable surface (PO), the experimental group presented lower absolute values than the control group in the synchronization between right foot toes and heels (CD), also with significant difference (p = 0.043). In the condition of eyes closed on an unstable surface (PC), the experimental group presented lower absolute values than the control group in the synchronizations between right foot toes and heel (CD) (p = 0.023), between right and left foot toes (BD) (p = 0.046) and between left heel and right foot toes (AD) (p = 0.038) with significant difference (Table 2).

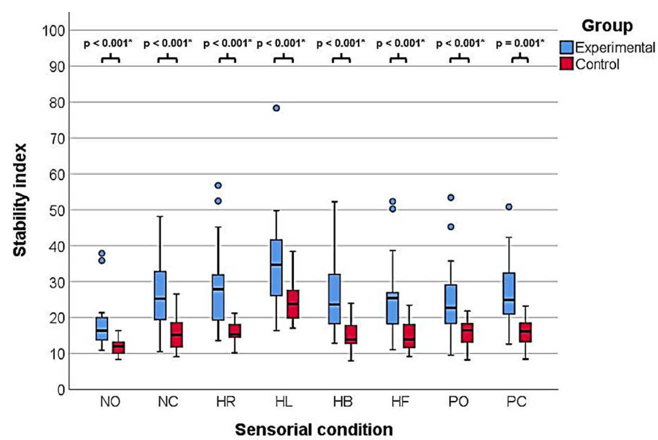

Figure 1. Box plot graph of stability index scores of experimental and control groups in the eight sensorial conditions of the *Tetrax Interactive Balance System* (*Tetrax IBS*™)

Caption: NO: stable surface, eyes open and face forward; NC: stable surface, eyes closed and face forward; HR: stable surface, eyes closed and head with a 45º rotation to the right; HL: stable surface, eyes closed and head with a 45º rotation to the left; HB: stable surface, eyes closed and head tilted back 30º; HF: stable surface, eyes closed and head tilted 30º forward PO: unstable surface, eyes open and face forward; PC: unstable surface, eyes closed and face forward. *Statistically significant value at 5% level (p<0.05)

Table 1. Descriptive values and comparative analysis of demographic data of the experimental and control groups and time of disease and anti-diabetic medication of the experimental group

Variable		Experimental (n = 20)		Control (n = 20)		Value of p
Gender	Female	15	75.0%	15	75.0%	p>0.999[A]
	Male	5	25.0%	5	25.0%	
Age in years (DP)	Mean	66.87 (8.39)		66.43 (8.13)		p = 0.866[B]
	Minimum	46.0		46.0		
	Maximum	83.0		81.0		
Weight in kilograms (DP)	Mean	71.48 (11.03)		66.52 (11.73)		p = 0.176[B]
	Minimum	52.0		49		
	Maximum	94.0		89		
Time of disease in months (DP)	Mean	183.75 (184.15)		-		
	Minimum	7.0		-		
	Maxim	756.0		-		
Antidiabetic medications	Metformina	6		-		
	Metformina + Glicazida	6		-		
	Metformina + Insulin	3		-		
	Insulin	2		-		
	Glicazida	1		-		
	Metformina + Vidagliptina	1		-		
	Metformina + Glicazida + Alogliptina	1		-		

[A]Student's t-test for independent samples; [B]Mann-Whitney U test

Caption: n: number of individuals; DP: standard deviation

Table 2. Descriptive values and comparative analysis between the experimental and control groups of the synchronization index in the eight conditions of the Tetrax Interactive Balance System (Tetrax IBS™)

Condition	AB		CD		AC		BD		AD		BC	
	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control	Experimental	Control
NO	-767.5 ± 177.7	-869.6 ± 82.71	-851.0 ± 151.6	-782.0 ± 175.0	609.1 ± 379.2	516.2 ± 314.9	815.8 ± 175.7	772.6 ± 193.7	-823.1 ± 259.6	840.5 ± 170.1	-901.2 ± 64.57*	-731.0 ± 265.4*
NC	-826.8 ± 147.4	-902.6 ± 51.16	-837.3 ± 164.6	-901.2 ± 76.0	714.1 ± 183.3	760.6 ± 133.1	827.6 ± 128.1	878.0 ± 66.86	-922.8 ± 37.46	-909.2 ± 68.31	-924.7 ± 40.32	-910.6 ± 56.98
HR	-740.8 ± 325.2	-871.0 ± 75.77	-817.6 ± 236.59	-840.61 ± 125.0	652.6 ± 379.5	635.6 ± 207.9	781.0 ± 236.2	864.0 ± 123.6	-890.7 ± 161.6	-882.6 ± 94.84	-924.7 ± 57.89	-865.7 ± 108.5
HL	-731.9 ± 259.9	-855.1 ± 124.2	-779.4 ± 232.8	-856.4 ± 133.5	620.1 ± 307.6	674.7 ± 227.3	769.3 ± 216.7	877.7 ± 95.78	-909.7 ± 72.7	-901.3 ± 115.2	-926.2 ± 46.31	-890.4 ± 165.1
HB	-805.7 ± 172.8*	-911.7 ± 54.61*	-838.2 ± 189.2	-882.2 ± 128.9	748.0 ± 223.2	723.7 ± 223.8	786.7 ± 164.5*	898.5 ± 62.66*	-923.0 ± 53.9	-909.8 ± 76.27	-941.7 ± 27.42	-884.7 ± 127.8
HF	-813.2 ± 176.9	-883.1 ± 119.9	-856.3 ± 145.2	-869.8 ± 126.6	623.4 ± 295.1	673.3 ± 248.1	850.0 ± 111.6	884.6 ± 79.70	-861.7 ± 146.7	-895.7 ± 81.98	-890.8 ± 110.2	-881.1 ± 124.3
PO	-731.7 ± 242.8	-700.7 ± 250.6	-655.3 ± 266.7*	-791.3 ± 224.3*	615.2 ± 306.4	720.3 ± 273.5	646.0 ± 251.8	681.3 ± 301.4	-918.1 ± 68.67	-941.4 ± 43.8	-897.5 ± 100.2	-923.5 ± 85.02
PC	-781.9 ± 175.8	-811.3 ± 140.8	-713.6 ± 255.3*	-862.7 ± 112.5*	699.2 ± 265.6	775.7 ± 167.6	676.5 ± 244.6*	820.6 ± 131.3*	-901.3 ± 90.16*	-952.5 ± 31.83*	-937.5 ± 44.79	-957.1 ± 21.29

Values are shown as mean ± standard deviation; Mann-Whitney U test; *Statistically significant value at the 5% level ($p < 0.05$)

Caption: NO: Open eyes on stable surface; NC: Eyes closed on stable surface; HR: Eyes closed, head rotated 45º to the right, on a stable surface; HL: Eyes closed, head rotated 45º to the left, on a stable surface; HB: Eyes closed, head tilted 30º backward, on a stable surface; HF: Eyes closed, head tilted 30º forward, on a stable surface; PO: Eyes open on unstable surface; PC: Eyes closed on unstable surface; AB: Synchronization index between left toe and heel platforms; CD: Synchronization index between right foot toes and heel; AC: Synchronization index between right and left heels; BD: Synchronization index between right and left foot toes; AD: Synchronization index between left heel and right foot toes; BC: Synchronization index between left foot toes and right foot heel

Regarding postural sway frequency rates (F1, F2-F4, F5-F6, F7-F8) of the control and experimental groups on the Tetrax IBS™ equipment in the condition of eyes closed on a stable surface (NC), head rotated 45° left on a stable surface (HL) and head tilted 30° forward on a stable surface (HF), the experimental group presented higher values than the control group in all frequency ranges, with significant difference. In the condition of open eyes on a stable surface (NO), the experimental group presented higher values than the control group in all frequency ranges, with a significant difference in the F2-F4, F5-F6 and F7-F8 ranges. In the condition of head rotated 45° to the right on a stable surface (HR), head tilted 30° backwards on a stable surface (HB) and eyes open on an unstable surface (PO), the experimental group presented higher values than the control group in all frequency ranges, with significant difference in the F2-F4, F5-F6 and F7-F8 ranges. In the condition of eyes closed on an unstable surface (PC), the experimental group presented higher values than the control group in all frequency ranges, with significant difference in the F2-F4 and F5-F6 ranges (Table 3).

There was a significant difference between the experimental and control groups in the fall risk index (Figure 3).

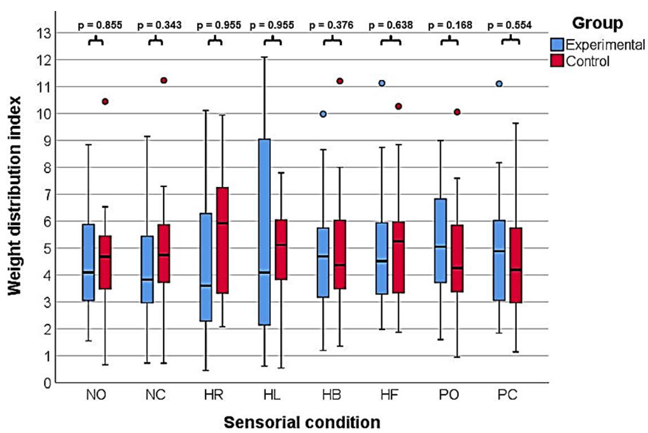

Figure 2. Box plot graph of weight distribution index scores of experimental and control groups in the eight sensorial conditions of the *Tetrax Interactive Balance System* (*Tetrax IBS*™)

Caption: NO: stable surface, eyes open and face forward; NC: stable surface, eyes closed and face forward; HR: stable surface, eyes closed and head with a 45º rotation to the right; HL: stable surface, eyes closed and head with a 45º rotation to the left; HB: stable surface, eyes closed and head tilted back 30º; HF: stable surface, eyes closed and head tilted 30º forward PO: unstable surface, eyes open and face forward; PC: unstable surface, eyes closed and face forward

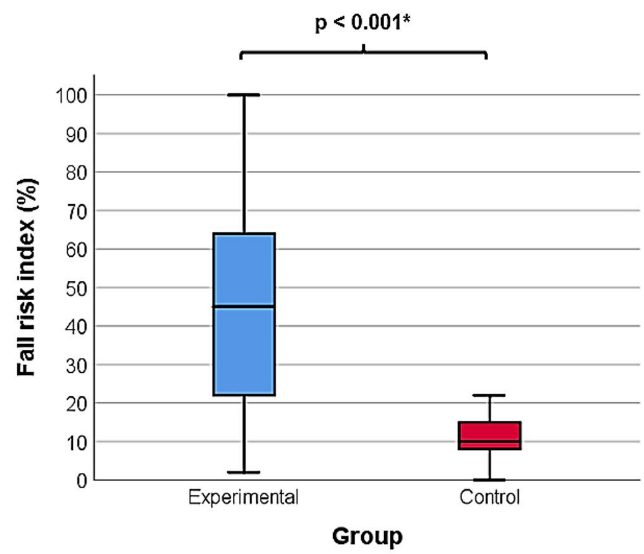

Figure 3. Box plot graph of fall risk index scores (%) of experimental and control groups in the *Tetrax Interactive Balance System* (*Tetrax IBS*™)

Caption: *Statistically significant value at 5% level (p<0.05)

Table 3. Descriptive values and comparative analysis between the experimental and control groups of postural sway frequency ranges (F1, F2-F4, F5-F6, F7-F8) in the eight conditions of the Tetrax Interactive Balance System (Tetrax IBS™)

Condition	F1			F2-F4			F5-F6			F7-F8		
	Experimental	Control	Value of p	Experimental	Control	Value of p	Experimental	Control	Value of p	Experimental	Control	Value of p
NO	15.5 ± 8.47	11.8 ± 4.9	0.106^A	8.17 ± 1.9	6.11 ± 1.6	0.001^B*	3.6 ± 1.4	2.3 ± 0.6	<0.001^B*	0.5 ± 0.2	0.4 ± 0.1	0.026^B*
NC	15.7 ± 7.4	11.1 ± 3.8	0.020^A*	13.8 ± 6.4	7.8 ± 1.5	<0.001^B*	5.1 ± 1.8	2.8 ± 1.1	<0.001^A*	0.7 ± 0.3	0.5 ± 0.2	0.006^A*
HR	14.1 ± 6.2	11.9 ± 5.2	0.183^B	12.6 ± 5.4	7.2 ± 1.8	<0.001^B*	4.6 ± 2.0	2.7 ± 0.7	<0.001^B*	0.7 ± 0.3	0.5 ± 0.2	0.007^A*
HL	14.2 ± 7.5	11.2 ± 7.6	0.040^B*	12.8 ± 7.8	7.1 ± 1.2	0.001^B*	4.7 ± 1.6	2.7 ± 0.7	<0.001^A*	0.7 ± 0.3	0.5 ± 0.2	0.027^A*
HB	15.1 ± 5.6	14.0 ± 8.7	0.989^B	12.3 ± 7.0	7.2 ± 1.7	<0.001^B*	4.5 ± 1.8	2.9 ± 0.6	<0.001^B*	0.7 ± 0.2	0.5 ± 0.1	0.034^A*
HF	18.8 ± 11.8	12.3 ± 6.0	0.018^B*	12.9 ± 7.5	7.5 ± 1.9	0.002^B*	4.8 ± 1.8	2.8 ± 0.6	<0.001^A*	0.7 ± 0.3	0.5 ± 0.1	0.017^B*
PO	22.8 ± 12.2	18.3 ± 8.8	0.289^B	11.2 ± 3.5	7.0 ± 1.9	<0.001^A*	5.3 ± 1.9	3.0 ± 0.8	<0.001^A*	0.9 ± 0.4	0.5 ± 0.1	0.001^B*
PC	23.1 ± 13.7	20.8 ± 22.4	0.102^B	14.8 ± 5.7	10.2 ± 3.8	0.005^B*	6.5 ± 2.7	4.6 ± 1.3	0.017^B*	1.0 ± 0.4	0.8 ± 0.3	0.060^B*

Values presented as mean ± standard deviation; ^A Student's t-test for independent samples; ^B Mann-Whitney U test; *Statistically significant value at 5% level (p < 0.05)

Caption: NO: Eyes open on stable surface; NC: Eyes closed on stable surface; HR: Eyes closed, head rotated 45º to the right, on a stable surface; HL: Eyes closed, head rotated 45º to the left, on a stable surface; HB: Eyes closed, head tilted 30º backward, on a stable surface; HF: Eyes closed, head tilted 30º forward, on a stable surface; PO: Eyes open on unstable surface; PC: Eyes closed on unstable surface; F1, F2-F4, F5-F6, F7-F8: Postural sway frequency ranges.

DISCUSSION

This study aimed at evaluating postural control of an experimental group of patients with T2DM who presented vertigo, dizziness, and/or imbalance using Tetrax IBS™ static posturography due to the high prevalence of vestibular and body balance dysfunction in individuals with DM[2,5,15]. Corroborating the literature, nearly one in three patients with T2DM interviewed reported vertigo, dizziness and/or imbalance. T2DM diagnostic time varied from some months to several years. A study found that patients with longer time of exposure to the disease have a greater chance of presenting vestibular dysfunction[5]. However, another survey did not identify any relationship between the duration of affection and vestibular dysfunction[2].

Little information is available in the literature about the interference of hyperglycemia and T2DM in the human body balance system; findings point to a possible correlation between peripheral vestibular diseases and insulin blood levels and glycemia[3,16]. Changes in blood glycemia concentration and particularly of blood insulinemia change the chemical structure of endolymph and can produce vertigo and dizziness[4]. Deterioration of sensorial functions related to body balance, particularly in challenging conditions, was also identified in T2DM without neuropathy; a dysfunction in any of the three sensory systems, vestibular, visual, and somatosensory, can cause significant impairment to maintenance of postural control[17].

The experimental and control groups were paired according to age and gender. Additionally, patients with diabetes with polyneuropathy and/or retinopathy were excluded, and healthy individuals, without vertigo, dizziness, and/or imbalance—common symptoms in aged individuals and women—were selected for the control group[18]. Thus, influence of these variables on the parameters employed for evaluation of postural control among the groups studied could be excluded, analyzing specifically the action of T2DM on the vestibular, visual, somatosensory structures and their interaction in the central nervous system.

The experimental group was composed mainly of older women, by the reports that DM prevails in old age and women[1].

DHI and vertigo and dizziness visual analog scale used to characterize the sample, indicated the intensity, incapacity, and shortcomings these symptoms caused in daily life. The experimental group showed a moderate impairment in quality of life in DHI[10,11,13]; the physical domain, which allowed for identification of the appearance of dizziness in certain positions or head movements[10], was the most compromised, followed by the functional and emotional domains, similar to the findings of another study in patients with vestibular dysfunction and T2DM[19]. Vertigo and dizziness visual analog scale[12] also quantified the intensity of dizziness as moderate[14] about average values, although in a little over half the number of cases the intensity was considered severe. Studies using this scale for evaluation of vestibular symptoms in T2DM patients were not found.

As for general stability measured using Tetrax IBS™, the experimental group was more unstable than the control group under all sensorial conditions evaluated. The lower values shown by the control group and by the individuals with T2DM were found with eyes open on a stable surface, the condition that has the lowest degree of difficulty in its execution, because the visual, proprioceptive and vestibular systems work jointly to maintain body balance[9]. The highest values presented by the control group and individuals with T2DM were found with eyes closed on an unstable surface, condition in which vestibular information has the greatest impact on body stabilization[9]. However, another study carried out with Tetrax IBS™ in patients with diabetes without polyneuropathy showed a higher stability index only in the condition with eyes closed and head backwards on a stable surface, in comparison with the control group[20]. A possible explanation for the difference in results would be that, in the present research, all patients of the group with T2DM presented vertigo, dizziness, and/or imbalance and thus were more susceptible to greater postural imbalance.

The weight distribution found in Tetrax IBS™ posturography, similar and with values considered normal in both the experimental and control groups, showed that the T2DM group with vertigo, dizziness and/or imbalance was able to distribute their weight with precision on the supporting base, a situation expected in view of the exclusion of cases with orthopedic disorders in the case series selection[9].

The experimental group showed a reduction in some postural sway synchronization indexes and increased in others, or results similar to those of the control group. However, findings in the eight conditions were symmetrical and positive or negative, as expected in healthy individuals[9], in both the control and experimental groups. This parameter, which measures coordination and the mutual innervation of the agonist and antagonist motor system of the lower extremities, showed alterations in the quality and efficiency of the compensatory and coordinating mechanisms between heels and toes in each foot, in simultaneous activation of the Tetrax IBS™ parallel plates, which suggests the interference of T2DM in these structures and in the fine postural control mechanism[9].

Individuals with T2DM presented greater postural sway than the control group in all frequency ranges, significant in most sensorial conditions, which points to the vestibular, visual, and somatosensory impairment or in the interaction between these systems. The dominance of sway in the low range (F1) suggests visual dysfunction; in the low-medium range (F2-F4), peripheral vestibular dysfunction; in the medium-high range (F5-F6), somatosensory dysfunction, and, in the high range (F7-F8), central vestibular dysfunction[9]. However, in patients with diabetes without neuropathy, when compared with the healthy control group, the Tetrax IBS™ showed higher values only in the medium-high frequency range of postural sway with eyes closed on stable surface, head rotated to the right and with rotation to the left[20]. One reason for this difference in findings could be that, in the present study, the group with T2DM was composed of people with diabetes with vertigo, dizziness, and/or imbalance and, thus, more prone to greater postural sway.

The fall risk in Tetrax IBS™, which was greater in individuals with T2DM than in the control group, was classified as moderate. The risk of falling is increased in DM patients[5,21] even before clinic signals are manifested[22], regardless of the occurrence of peripheral neuropathy. DM patients are more likely to suffer falls due to the decrease of the sensorimotor and musculoskeletal function and to neuromuscular deficits, foot and body pain, and pharmacological complications[6].

The Tetrax IBS™ uses parameters and procedures different from those of other types of posturography, which makes a quantitative comparison of results more difficult. Other types of posturography also identified similar performance or increased postural instability, when visual, vestibular or somatosensory cues were absent, distorted or imprecise in T2DM patients without neuropathy in comparison with control groups made up of healthy individuals[22-28].

The Tetrax IBS^{TM} static posturography identified differences between T2DM and healthy individuals. The hypothesis of vestibular sensory organ dysfunction in T2DM can be advanced and supported not only by the complaints of vertigo, dizziness and/or imbalance of patients with diabetes but also by the findings of this research, of postural control alterations characterized by instability, by the increase and desynchronization of postural sway and risk of falling, suggesting the existence of vestibular, visual and somatosensorial dysfunction or dysfunction of their interaction in the central nervous system.

Considering the relevant prevalence of vertigo, dizziness, and/or imbalance in the population with T2DM interviewed, it is recommended that, as an important part of the evaluation of patients with this disease, an anamnesis with the identification of these symptoms be complemented by an neurotological semiological exploration, including posturography.

Future investigations, including other procedures for evaluation of the vestibular function and body balance are indispensable to help elucidate the physiopathological mechanisms of vestibular dysfunction in T2DM patients.

CONCLUSION

Individuals with T2DM with vertigo, dizziness and/or imbalance may present postural control disorders at posturography, characterized by alterations in general stability, synchronization of postural sway, postural sway frequency ranges and fall risk, suggesting vestibular, visual and somatosensory dysfunction or dysfunction in their interaction in the central nervous system.

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