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original article

Postural control and functional balance in individuals with diabetic peripheral neuropathy

Controle postural e equilíbrio funcional em indivíduos com neuropatia diabética periférica

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Abstract – Diabetic Peripheral Neuropathy (DPN) brings on reduced somatosensation, which can lead to changes in postural control. The objective of this study was to evaluate postural control in a standing position and in different conditions, as well as functional balance in individuals with DPN, make the correlation between the results obtained from the postural control assessment with the values from the functional balance test and compare the results obtained in the neuropathy group with those of the control group, checking for possible differences between the evaluation conditions of both groups. The study included 13 women with DPN (NG) and 17 non-diabetic women (CG). Postural control assessment was performed by kinemetry in the following conditions: eyes opened (EO), eyes closed (EC), and semi-tandem (ST). The data was processed in MATLAB and the following variables were generated: mean amplitude of oscillation (MAO) in the anterior-posterior (AP) and medial-lateral (ML) direction; and average speed of oscillation (ASO) in AP and ML direction. Functional balance was assessed by the *Timed Up and Go Test*. There was significant difference between the groups (p≤0.005) in MAO-AP EO and EC, MAO-ML EC and ST, and ASO-ML ST. There were differences between the conditions EO and ST (p≤0.005) and EC and ST (p≤0.005) for the variables MAO-ML and ASO-ML with greater damage to the NG, which also had a lower functional balance (p=0.001). ML instability was positively correlated with functional imbalance. The results show a change in the postural control system in the DPN, which could lead these individuals to a higher risk for falls and functional impairment.

Key words: Balance; Physiotherapy; Diabetic neuropathies.

Resumo – *A Neuropatia diabética periférica (NDP) cursa com redução somatossensitiva que pode levar a alterações no controle postural. O objetivo do estudo foi avaliar o controle postural na postura ereta, em diferentes condições, e o equilíbrio funcional em indivíduos com NDP, correlacionar os resultados obtidos na avaliação do controle postural com os valores do teste do equilíbrio funcional e comparar os resultados obtidos no grupo neuropata com o grupo controle, verificando as possíveis diferenças entre as condições de avaliação em ambos os grupos. Participaram do estudo 13 mulheres com NDP (GN) e 17 mulheres não diabéticas (GC). A avaliação do controle postural foi realizada por cinemetria nas condições: olhos abertos (OA), olhos fechados (OF) e semi tandem (ST). Após processamento no MATLAB, foram geradas as variáveis: amplitude média de oscilação (AMO) na direção ântero-posterior (AP) e médio-lateral (ML); e velocidade média de oscilação (VMO) na direção AP e ML. O equilíbrio funcional foi avaliado pelo Timed Up and Go Test. Houve diferença significante entre os grupos (p≤0,005) na AMO-AP OA e OF, AMO-ML OF e ST e VMO-ML ST. Houve diferença entre as condições OA e ST (p≤0,005) e OF e ST (p≤0,005) para as variáveis AMO-ML e VMO-ML, com maior prejuízo para o GN, que também apresentou um menor equilíbrio funcional (p=0,001). A instabilidade ML foi correlacionada positivamente com o desequilíbrio funcional. Os resultados nos mostram uma alteração no sistema de controle postural na NDP, o que pode levar estes indivíduos a um maior risco a quedas e prejuízos funcionais.*

Palavras-chave: *Equilíbrio; Fisioterapia; Neuropatias diabéticas.*

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INTRODUCTION

Currently, Diabetes Mellitus (DM) has been the subject of research worldwide due to the high and increasing prevalence of this disease[1] that leads to complications such as diabetic peripheral neuropathy (DPN). DPN leads to a decrease in nerve conduction velocity[2], generally progressing in a distal to proximal direction. The person with this problem has impairment of superficial and deep sensitivity of the lower limbs, resulting in a deficient balance[3] due to the relationship between the sensitivity of the feet and maintaining postural control[4].

Some authors have studied postural control, checking decreased stability both in the diabetic and neuropathic population[5,6]. Evaluations of postural control in the diabetic population, with or without neuropathy, have been held in different conditions: with eyes closed[7], single leg stance[8], and tandem stance position[5]. Other authors have evaluated the balance of elderly diabetics using the Timed Up and Go Test (TUGT)[9,10]. However, literature lacks studies on postural control associated with different degrees of difficulty.

The decrease in postural control implies in risk of falls in neuropathic individuals[8], which can bring functional impairment[11] and high costs for the public health system. It is therefore necessary to investigate postural control in the neuropathic population in order to understand in which situations these individuals performed worse. These results can facilitate an appropriate treatment program for improving stability and preventing functional impairment for this population.

Furthermore, most studies on postural control in DPN have been concerned about using sophisticated equipment of good accuracy[6]; however, such devices have a high cost and therefore are not feasible for clinical practice.

The lack of assessment of postural control in neuropathic diabetics in different levels of difficulty, along with the assessment of functional balance by means of a simple test, justifies this study, which is aimed at assessing postural control in standing position in different conditions and the functional balance in individuals with diabetic peripheral neuropathy, correlating the results obtained from assessing their postural control with the values of the functional balance test, and comparing the results obtained in the neuropathic group with those of the control group, checking for possible differences between the assessment conditions in both groups.

METHODS

Subjects

Thirty women participated in the study between the ages of 55 and 70, and they were divided into two groups: the neuropathy group (NG) was composed of 13 women with type 2 DM and affected by DPN, and the control group (CG) had 17 non-diabetic women. The participants of the NG were referred from the University Extension Project "Diabetic Foot

Program" from the College of Sciences and Technology of the São Paulo State University (FCT/UNESP) in Presidente Prudente.

The research was conducted in the Laboratory of Clinical Studies in Physiotherapy (LECFisio) at FCT/UNESP. This study was approved by the Local Committee on Research Ethics under protocol number 30/2010. Each individual was made aware of the procedure to be performed and, accordingly, signed a Consent Form.

Procedures

Initially, anthropometric data was collected such as body weight, height, and body mass index (BMI). The postprandial glycemia test was performed in order to confirm DM in the NG and exclude possible diabetics in the CG. The insensitivity to the Semmes-Weistein monofilament of 10g (SorriBauru®, Brazil) on at least one point tested[12] and the score of ≥8 in the Michigan Neuropathy Screening Instrument (MNSI)[13] were used as inclusion criteria for NG. The CG showed normality in these tests.

In order to gain a greater level of control over the physical activity, the Modified Baecke Questionnaire for Older Adults was applied as validated by Mazo et al.[14] All participants had similar levels of physical activity, so this factor did not affect the results. The Dizziness Questionnaire[15] was applied in an attempt to minimize changes in postural control resulting from vestibular disorders. All participants were also asked about the presence of visual deficiencies, and those that presented a significant and uncorrected visual deficiency were excluded, as well as those using medications that could affect their balance, and in this case the individual was also excluded from the study.

In both groups, individuals with musculoskeletal deformities were excluded such as plantar ulcers, lower limb amputation, realization of gait with orthosis; patients with claudication; and also excluded were individuals with a disease in the central nervous system or other peripheral diseases causing the person to be incapable of understanding the tests.

Assessment of postural control and functional balance

In order to evaluate the performance of the postural control system, the body's anterior-posterior and medial-lateral oscillation was analyzed by a kinematics system while maintaining a standing position. To do so, the participants were asked to remain barefooted with their arms down along the body, looking at a fixed point on the wall 2 meters away while remaining as still as possible for 30 seconds in three conditions: Condition 1 (EO): Upright posture with eyes opened and with 2 feet on the floor, parallel and aligned with the shoulders; Condition 2 (EC): upright posture with eyes closed and 2 feet on the floor; Condition 3 (ST): upright posture with eyes open and semi-tandem base[16] with the feet placed one in front of the other (dominant foot in front) with the hallux touching the medial edge of the heel of the contralateral foot. The semi-tandem position was chosen instead of the tandem stance position because the semi tandem position is easier for the population evaluated, which, besides being elderly, also had some neuromotor disadvantages. To determine the dominant leg, the individual was asked with which leg he or she would prefer to kick a ball. Three attempts were done for each condition, and between each condition a rest interval of one minute was given if the subject needed it.

Two digital video cameras were used for the evaluation of the brand PANASONIC® (NV-GS320, Japan) with a 60Hz sampling frequency. They were positioned on tripods located behind the individual for filming a reflective marker, two centimeters in diameter, set at the level of the T12 vertebra, making it possible to record the dislocations of the body in a standing position[17]. The filming of the two cameras was synchronized by a manually-controlled LED at the beginning of each trial. Prior to data collection, a filming was done for system calibration of tridimensional reference with 12 control points and volume of 0.70 x 1.34 x 0.90 m, respectively for length, height, and depth.

This was followed by the transfer of the images to the *Ariel Performance Analysis System* (APAS, version 1.4), allowing the selection of sections corresponding to 30 seconds of each evaluation and also scanning the marker with its coordinates transformed into 3D images (DLT, *Direct Linear Transformation*). Next, the data was filtered through a Butterworth filter, fourth-order low-pass, and frequency cutoff of 5Hz. The averages of the three trials were analyzed for each situation. The treatment of the data and computation of the variables were performed using routines written in MATLAB (Math Works, version 7.8.0), and the following variables were generated in the domain of time: Mean amplitude of oscillation (MAO) in the anterior-posterior (AP) and medial-lateral (ML) direction; and average speed of oscillation (ASO) in AP and ML direction. The amplitudes, given in cm, correspond to variance of the data, which is obtained by calculating the standard deviation of the body displacement of the respective trial after removing the average and linear trend. The velocities in the AP and ML directions were given in centimeters/second. For both variables (MAO and speed), a lower value is representative of less oscillation and hence a better performance of the postural control system.

Finally, to assess the dynamic functional balance, the *Timed* Up and Go Test (TUGT)[18] was used that evaluates the time that the individual spends to rise from a chair, walk a distance of three meters, turn around, return to the chair, and sit down again. This test assesses the balance in the transfer from a sitting to a standing position, stability in walking, and changes in the course of the gait as developed by Cordeiro et al.[10].

Statistical Analysis

The continuous variables were expressed as average, standard deviation, and confidence interval of 95% (CI95%). The distribution of normality was verified by the Shapiro-Wilk test. A student's *t*-test or Mann-Whitney test was applied to compare between the averages of the control and neuropathy group when the data did not meet the assumption of normality.

The ANOVA test of repeated measurements was applied to check the differences between the conditions (EO, EC, and ST) as well as the relationships between the group and carrying out an assessment of the postural control for the dependent variables: MAO-AP, MAO-ML, ASO-AP, ASO-ML. The Bonferroni post hoc test was used to locate the differences between the condition factor of the postural control assessment. The localization of the differences for group interaction versus condition was done by analyzing the confidence intervals (CI95%) in which the intervals with overlapping values indicate no significant differences.

The homogeneity of the covariance matrices was verified by the Box's M test. The assumption of sphericity was examined by the test and Mauchly's W's, and if this one was violated, the Greenhouse-Geisser correction was applied. Pearson's or Spearman's correlation was used when necessary to check the correlation between the variables obtained by static evaluation (MAO-AP, MAO-ML, ASO-AP, ASO-ML) with that obtained by the dynamic evaluation (time obtained in TUGT). In all the analyses, the significance level was 5% and the program used for statistical analysis was SPSS (Statistical Package for Social Sciences, version 19.0).

RESULTS

In the characterization of the sample described in Table 1, the NG population showed higher postprandial blood glucose levels, confirming the condition of diabetes and increased BMI. The average points of no sensitivity to the Semmes-Weinstein monofilament of 10g in the NG was 3.23±2.98 and the average score on the Michigan Neuropathy Screening Instrument for this same group was 10±1.83, confirming neuropathy.

Table 1. Characteristics of the sample (Average ± standard deviation and p-value)

Variables	CG	NG	p-value
Age (years)	62.41±6.05	63.46±6.91	0.76
Body mass (kg)	66.16±9.27	76.55±18.11	0.07
Height (m)	1.56±0.07	1.57±0.06	0.72
BMI (kg/m^2)	26.98±3.22	32.98±6.90	0.01*
Glycemia (mg/dL)	116.76±21.12	162.08±44.02	0.01*

Control Group (CG) n=17; Neuropathy Group (NG) n=13; * differ statistically by the student's t-test ($p<0.05$)

The evaluation using the Mann-Whitney test for the variables related to the analysis of postural control showed a significant difference between the groups for MAO-AP EO, MAO-AP EC, MAO-ML EC, MAO-ML ST, and with ASO-ML ST with higher values for the NG in all variables (Table 2).

The ANOVA test for repeated measurements showed differences in the variables MAO-ML and ASO-ML among conditions within the groups. The Bonferroni post hoc test showed these differences between the conditions EO and ST, and EC and ST (Table 2). The ANOVA test showed interaction between group and condition ($p<0.005$), and this interaction was verified by analysis of the confidence intervals in the variable MAO-ML, considering that for the condition ST in the variable MAO-ML there were significant differences observed by the analysis of the confidence intervals for the groups, and in the variable ASO-ML there were no differences found between groups for the condition ST, in which occurred the overlapping of the confidence intervals (Table 2).

Regarding the results obtained in TUGT, the student's *t*-test revealed a significant difference between the groups (p=0.001) with an average duration of 10.19±1.94 seconds for the CG and 14.07±2.98 seconds for the NG.

For Pearson's correlation, a significant positive correlation was observed between the values of time obtained in TUGT with MAO-ML EO (R=0.478, p≤0.001), MAO-ML ST (R=0.694, p<0.001), and ASO-ML ST (R=0.457, p<0.05).

Table 2. The average and confidence interval (IC95%) of the variables in the postural control assessment in the control (CG) and neuropathy (NG) group in different evaluation conditions

Variable	Condition	CG (n=17)	NG (n=13)
MAO-AP (cm)	EO	0.15(0.10-0.21)*,a	0.23(0.16-0.29)*,a
	EC	0.17(0.13-0.35)*,a	0.22(0.09-0.35)*,a
	ST	0.18(0.10-0.27)a	0.21(0.11-0.31)a
MAO-ML (cm)	EO	0.08(0.05-0.10) a	0.11(0.08-0.14) a
	EC	0.08(0.05-0.11)*,a	0.11(0.07-0.14)*,a
	ST	0.21(0.16-0.26)*,#, b	0.36(0.30-0.41)*,#, c
ASO-AP (cm/s)	EO	0.61(0.48-0.78)a	0.76(0.58-0.93) a
	EC	0.74(0.45-1.94) a	0.77(-0.10-1.64) a
	ST	0.98(0.47-1.60) a	0.89(0.22-1.55) a
ASO-ML (cm/s)	EO	0.30(0.23-0.37) a	0.33(0.25-0.41) a
	EC	0.28(0.23-0.40) a	0.31(0.21-0.40) a
	ST	0.59(0.43-0.74)*,#, b	0.86(0.67-1.04)*,#, b

MAO = Mean Amplitude of Oscillation; ASO = Average Speed of Oscillation; AP = anterior-posterior; ML= medial-lateral; EO= Eyes Opened; EC = Eyes Closed; ST = Semi-Tandem base; * = p≤0.05 (Mann-Whitney test) for comparison between the control and neuropathy group within each condition; # = differs statistically from the other conditions within a group for a variable by the Bonferroni post hoc test (p≤0.05); the different letters determine the significant difference between condition and group within a variable

DISCUSSION

The present study evaluated postural control using the variables MAO-AP, MAO-ML, ASO-AP, and ASO-ML in different degrees of difficulty. It was observed that the condition of DPN led to an increase in MAO-AP in NG both in the condition of EO and in the condition of EC, as well as in MAO-ML in the condition of EC and ST.

The MAO-AP was more affected by vision and MAO-ML by the decrease of the support base considering that the first presented a change even with EO, and second only with EC and a decreased base. It is believed that the MAO-AP failed to show changes in the ST position in the NG because this position determines the reduction of the polygon of support in the ML direction, while it also increases the polygon in the AP direction with an increase in stability in the latter direction.

In agreement with our findings, authors such as Lafond et al.[7] and Ajmed et al.[19] found a higher AP oscillation even with the presence of vision. The increase of AP oscillation in the population with DPN, even with EO, is probably due to the posture strategies used considering that, in order to maintain AP stability, the strategy most used is of the ankle[20], which is more deficient in individuals with DPN[21]. ML stability, on the other hand, is more influenced by the hip joints with alternating activity of the abductor muscles and adductors[20]. Thus, the preservation of ML stability with EO can be associated with less involvement of the proximal joints in neuropathic individuals[21].

MAO-ML was higher in the NG for the two conditions that demanded the most from the postural control system (EC and ST), considering that in the condition of ST the NG presented more instability in relation to the other conditions since these individuals also had a higher rate of oscillation in the ML direction. Lafond et al. [7] also observed greater ML oscillation in neuropathic individuals in the absence of vision, and Razuk et al.[5] found a higher amplitude of ML oscillation in diabetic subjects in the condition of greater demands of postural control.

When we compared the conditions and the interaction between group and condition, differences were observed in MAO-ML and ASO-ML between the conditions EO and ST, EC and ST. The interaction between condition and group was also observed for the variable MAO-ML, and the NG had the worse instability in this condition, which means that neuropathy plus the ST condition worsens ML instability. The sensory and biomechanical problems of these patients in the ankle joint leads to a compensation with information more readily available at the hip, bringing an increase of sensitivity to information in the ML axis[21] and therefore the individual responds with the strategy of the hip at any small disturbance external to the postural control system, causing greater oscillation.

We expected that there would also be a difference between the conditions EO and EC for the groups; however, no difference was found when these situations were compared. We could consider that, in this case, vision did not have a big influence, probably because of the somatosensory system, which is the most important sensory component for maintaining posture control[22]. When the groups were compared in the evaluation with EC, there was no difference in the results of MAO-AP and MAO-ML, with greater oscillation in the NG due to the fact that these individuals have a reduction in their somatosensory sensitivity[3].

The TUGT revealed a greater functional imbalance in the NG population determined by a significantly higher time in carrying out the test when compared to the CG. Other authors also found a decrease in functional balance in the neuropathy population through TUGT[9,10]. The performance in the test is affected by reaction time, muscle strength of the lower limbs, balance, and gait difficulties[23]. Higher levels in the time of doing this test may indicate a reduction in balance in daily activities and a decrease in the average speed of gait[24].

We also found that ML stability is related with functional stability. We can infer that the neuropathic individuals evaluated in this study have a greater risk for falls since they have a more accentuated ML instability in the ST condition when compared with the control group, and this instability is associated with a higher risk of falling[25], and they do the TUGT over a period of time longer than 14 seconds, keeping in mind that this value may be related to a higher risk for falling in older people[26].

The evaluations used in this study were relevant since the method for analyzing the displacement of the center of mass could be measured by a single marker located on the backbone near the hip[27]. The importance of assessing postural control in different conditions should also be pointed out, which allow a better verification of the relationship between sensory and motor input[28]. Furthermore, in relation to TUGT, because it is a test of easy applicability and low cost, it can be widely used in clinical practice to provide information about balance in the population with DPN.

This study made it possible to expand knowledge in the field of rehabilitation, in which the findings show that the postural control system may be deficient in neuropathic diabetics, and because of this these people have difficulty receiving sensorial information about how to respond appropriately to movement disturbances[29].

Thus, there is a need for rehabilitation programs to work with the sensory component by means of therapeutic exercises aimed at tactile and proprioceptive improvements, together with the motor component, facilitating muscular responses, especially in the ankle joints so that postural strategies can be more effective.

This study had limitations in the sense of not assessing the proprioceptive and motor component more accurately by evaluating the muscle strength and range of movement of the distal joints. Other studies should carry out these evaluations so as to clarify which of the aspects altered in the motor control have the greatest influence on stability during a standing position in individuals with DPN.

CONCLUSIONS

It was possible to verify that neuropathic individuals fluctuate more than those people without neuropathy in both the AP and ML direction, and that both groups have greater instability in the ST condition with greater MAO-ML and ASO-ML, and the person with neuropathy was more susceptible to the condition of ST for the variable MAO-ML. The difference in functional balance was also observed by the longer time it took for the NG to do the TUGT and that there was a significant and positive correlation between medial-lateral instability and functional balance.

The results show a change in the postural control system in individuals with DPN in different conditions evaluated, which is most likely due to motor impairment, especially in the ankle's strategies for maintaining posture control, as well as the change in the somatosensory system. The combination of these changes may lead these individuals to an increased risk for falling and functional impairment. The evaluations used in this study allow us to understand the neuromotor deficit present in the postural control system in individuals with DPN and then base treatments that are more adequate.

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