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Original Article

Balance and ankle muscle strength predict spatiotemporal gait parameters in individuals with diabetic peripheral neuropathy

Marcela R. Camargo [a,b], José A. Barela [b,c], Andréa J.L. Nozabieli [a], Alessandra M. Mantovani [a], Alessandra R. Martinelli [a], Cristina E.P.T. Fregonesi [a,*]

[a] Laboratory of Clinical Studies in Physical Therapy, School of Sciences and Technology, Sao Paulo State University, Presidente Prudente, SP, Brazil
[b] Laboratory of Movement Analysis, Institute of Physical Activity and Sport Sciences, Cruzeiro do Sul University, Sao Paulo, SP, Brazil
[c] Institute of Biosciences, Sao Paulo State University, Rio Claro, SP, Brazil

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ABSTRACT

Aims: The aims of this study were to evaluate aspects of balance, ankle muscle strength and spatiotemporal gait parameters in individuals with diabetic peripheral neuropathy (DPN) and verify whether deficits in spatiotemporal gait parameters were associated with ankle muscle strength and balance performance.

Materials and methods: Thirty individuals with DPN and 30 control individuals have participated. Spatiotemporal gait parameters were evaluated by measuring the time to walk a set distance during self-selected and maximal walking speeds. Functional mobility and balance performance were assessed using the *Functional Reach* and the *Time Up and Go* tests. Ankle isometric muscle strength was assessed with a handheld digital dynamometer. Analyses of variance were employed to verify possible differences between groups and conditions. Multiple linear regression analysis was employed to uncover possible predictors of gait deficits.

Results: Gait spatiotemporal, functional mobility, balance performance and ankle muscle strength were affected in individuals with DPN. The *Time Up and Go* test performance and ankle muscle isometric strength were associated to spatiotemporal gait changes, especially during maximal walking speed condition.

Conclusion: Functional mobility and balance performance are damaged in DPN and balance performance and ankle muscle strength can be used to predict spatiotemporal gait parameters in individuals with DPN.

1. Introduction

Diabetes mellitus (DM) is a chronic disease which causes the greatest rate of morbidity and mortality worldwide [1], not only due to the disease per se, but due to its chronic complications [2]. In particular diabetic peripheral neuropathy (DPN) is the main complication among those co-morbidities and affects approximately 40–80% of individuals with diabetes [3–7].

Peripheral nerve injuries occur insidiously and start with reduced sensitivity followed by motor nerve impairment [8]. During the progression of clinical symptoms, the sensory-motor system is entirely affected, leading to tissue damage, loss of muscle strength, altered foot structure and ultimately disrupting gait and balance control [7,9]. As a consequence, gait pattern is altered, possibly resulting of adaptations that attenuate the effects of all these sensory-motor changes [10,11].

The risk for fall-related injuries increases in patients with DPN [12], since neuropathy further compromises postural control mechanisms and performance. Furthermore, the disease also leads to muscle weakness due to the lack of muscle activation [13] and the involvement of the myofascial structure [14,15]. Therefore, it is unsurprising that individuals with DPN commonly have impaired gait performance [16].

Understanding the effects of DPN on muscle strength, gait and balance performance remains important and several studies have been designed to investigate possible relationships among these factors [17–19]. Nevertheless, whether sensory-motor changes are

* Corresponding author at: Laboratory of Clinical Studies in Physical Therapy, School of Sciences and Technology, São Paulo State University, Rua Roberto Simonsen, 305, CEP 19060-900 Presidente Prudente, SP, Brazil.
Tel.: +55 18 3229 5825; fax: +55 18 3229 5550.
E-mail address: cristina@fct.unesp.br (Cristina E.P.T. Fregonesi).

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directly related to spatiotemporal gait parameters in individuals with diabetic remains unclear. Examining how changes in muscle strength, gait and balance are correlated in patients with DPN while performing different tasks might uncover important facets about daily tasks and provide information that would allow the implementation of therapeutic procedures to avoid or minimize such changes in individuals with DPN.

Therefore the goals of this study were, first, to evaluate gait spatiotemporal parameters, functional mobility, balance performance, and ankle muscle strength and, second, to verify whether deficits in spatiotemporal gait parameters are associated to ankle muscle strength and balance performance in individual with DPN.

2. Subjects

2.1. Ethical aspects

This study was conducted in accordance with the ethical principles of the Helsinki Declaration, revised in 2000. Each participant included in this study read and signed a consent form. All procedures were approved by the Institutional Ethics Committee at the São Paulo State University (FCT/UNESP; protocol # 251/2008).

2.2. Participants

A sample of 30 patients with DPN was recruited from a group of patients who had been enrolled in an institutional service offered to individual with diabetes. In addition, 30 participants from the same metropolitan area were invited to join the study forming the control group.

2.3. Inclusion criteria

The postprandial glucose test was administered to participants in both the experimental and control groups, confirming that participants in the experimental group had DM and that participants in the control group were free of DM. To confirm the DPN diagnosis, the *Michigan Neuropathy Screening Instrument* (MNSI) test [20] and the somatosensory test using *Semmes-Weinstein* monofilaments according to previously studies [21,22] were employed in both feet. Participants in the experimental group had scores above 8.0 on the MNSI test [23,24] and an insensitivity to the 10 g *Semmes-Weinstein* monofilament, which corresponds to 5.07 on the MNSI scale [25].

2.4. Exclusion criteria

To assure the homogeneity of individuals with DM in our sample, the following exclusion criteria were used: (a) osteoarticular deformities; prior or current plantar ulcers; any lower limb amputation; (b) walking with assistive device; (c) any neurological disease which would affect gait performance or claudication; (d) any lower limb pain; (e) significant and non-corrected visual deficit; (e) body mass index (BMI) higher than 40 kg/m^2; (f) up to 5 years of DM diagnosis and no-insulin receiver; (g) absence of other DM morbidities (e.g. nephropathy or retinopathy) and (f) an disability to perform any of the tests.

3. Materials and methods

3.1. Gait assessment

Gait assessment followed procedures used by Nagasaki et al. [26]. Participants walked along an 11 m pathway, first, at preferred and then at maximum walking speeds. In this walking pathway, two markers placed at 3 and 8 m from the beginning were used to define the distance in which the walking steps were counted and the elapsed time to travel the 5 m distance was obtained. Therefore, the first and last 3 m of the walking pathway were not considered for analyses, since acceleration and deceleration could occur, thereby affecting walking speed measurements.

After obtaining the number of steps and the elapsed time to travel the 5 m distance, step amplitude and cadence were calculated according to Eqs. (1) and (2), respectively.

$$\text{Step Length} = \frac{\Delta\text{Distance}}{\text{Steps Number}} \tag{1}$$

$$\text{Cadence} = \frac{\text{Steps Number}}{\Delta\text{Time}} \tag{2}$$

According to Nagasaki et al. [26], to calculate the average step length and cadence, it is necessary to correctly consider each participant's lower limb length. Therefore, Eq. (3) was applied to correct step-length and Eq. (4) to correct step-cadence.

$$\text{Step Length}_{\text{Corrected}} = \frac{\text{Step Length}}{\left\{\frac{\text{Lower Limb Height}}{\text{Mean Lower Limb Lenght}}\right\}} \tag{3}$$

$$\text{Cadence}_{\text{Corrected}} = \text{Cadence}\left\{\frac{\text{Lower Limb Height}}{\text{Mean Lower Limb Length}}\right\}^{1/2} \tag{4}$$

Finally, mean speed displayed as one participant traveled along the pathway was obtained by applying Eq. (5).

$$\text{Speed}_{\text{Corrected}} = \text{Step Length}_{\text{Corrected}} \times \text{Cadence}_{\text{Corrected}} \tag{5}$$

Lower limb length was calculated according to Eq. (6). The length of the trunk was calculated based on Eq. (7). To determine the height of the trunk, the participant was asked to sit on a bench with a standardized height (0.5 m), where the distance was measured between the floor and the upper surface of the head.

$$\text{Lower Limb Length} = \text{Height} - \text{Trunk Length} \tag{6}$$

$$\text{Trunk Length} = \text{Overground} \overset{\text{Distance}}{\longleftrightarrow} \text{Vertex} - \text{Bench Height} \tag{7}$$

3.2. Functional mobility and balance assessment

Two clinical tests were conducted to evaluate functional mobility and balance performance. The "*Functional Reach*" (FR) test that has been suggested as a precise, valid, and reliable clinical balance instrument, with an established sensitivity to change (coefficient of variation = 0.025, intra-class correlation = 0.92, responsiveness index = 0.97) [27]. More specifically, the FR test measures the maximum distance that a person can reach forward, beyond his or hers arm length, while standing in a fixed position. Each subject was required to practice twice, with each elbow fully extended, and then performed a third trial which was considered for analysis.

The second test employed was the "*Time Up and Go*" (TUG) test [28] which also has a good intra-rater and inter-rater reliability (r = 0.99 and 0.98, respectively) [29]. This test is based upon the time (in seconds) that a participant takes to stand up from an armchair, walk a distance of 3 m, turn, walk back, and sit down on the chair. The TUG was developed originally as a clinical measure of balance in elderly, based on an observer's perception of the performer's risk of falling during the test.