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SHORT COMUNICATION

Dual-tasking effects on functional performance in individuals with diabetes and diabetic peripheral neuropathy

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Abstract

Background: Cognitive dysfunction and neuropathy are common complications of diabetes mellitus that can significantly affect movement quality and daily activities. **Objective:** This study aimed to investigate how motor and cognitive dual-tasking impacts functional performance in individuals with diabetes and diabetic neuropathy. **Methods:** The study is a cross-sectional observational study that involved 55 adults under 60 years of age, divided into three groups: diabetes (DG), diabetic peripheral neuropathy (DNG), and a healthy control group (CG). Participants underwent assessments using the Michigan Neuropathy Screening Instrument, the Montreal Cognitive Assessment, and functional tests: Timed Up and Go test, Timed Up and Go with Dual-Task and a 10-meter gait speed test. All tests were controlled by an accelerometer. **Results:** Dual-tasking increased the time needed to complete the TUGWDT tests for all groups (27,7% in CG, 18,8% in DG and 24,7% in DNG). Individuals with diabetic peripheral neuropathy had slower gait speeds than those without neuropathy (17% lower) and healthy controls (35% lower). Diabetes alone also reduced gait speed compared to healthy individuals (22% lower). The cost of dual-tasking was more pronounced in healthy individuals. **Conclusion:** Diabetes and its complications affect dual-tasking performance and gait speed. This highlights the possible need for physical and cognitive interventions to improve patient's quality of life.

Keywords: Gait; function performance; type 2 diabetes.

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BACKGROUND

Diabetes mellitus (DM) is one of the epidemic community diseases that most affects the world's population this century. In 2021, the International Diabetes Federation (IDF) estimated that 537 million people had diabetes, which is expected to reach 643 million by 2030[1]. Peripheral neuropathy (PN) is the most common diabetes complication, affecting up to 50% of this population[2]. Individuals with diabetic peripheral neuropathy (DPN) show significant impairments in gait and turning performance when engaged in dual tasks, such as walking while performing a cognitive task. This is due to the increased cognitive demand required to compensate for the lack of sensory feedback, leading to greater gait variability and instability[3,4].

Dual-tasking (DT) is a paradigm that explores a demanding secondary task concomitant with a motor task. It is commonly used to study the degree of automaticity of movement[5]. In addition, the concept of dual-tasking, which involves simultaneously performing a cognitive task while executing a motor task, is crucial to understanding how executive function and gait interact in patients with diabetes and DPN[6].

Increasing cognitive load and altering neural activation patterns in the brain can impair motor performance during DT[7]. However, there are still gaps in knowledge about how this interaction between dual-task, diabetes, and diabetic peripheral neuropathy affects gait performance. Studies in elderly neuropathic patients suggest a common pattern of lower limb muscle weakness, and impaired postural balance and gait performance[3], such as decreased stride length and gait speed, prolonged double support time, increased stride width and gait variability[8].

In other study with older adults with type 2 diabetes, the authors found that reduced cognitive function further affects gait, irrespective of the presence of neuropathy. Older adults with diabetes walked slower, took shorter strides during all walking conditions, and showed more gait variability, especially during dual-task conditions compared with controls[9].

Thus, this study aimed to verify how different diabetic conditions affect functional performance during dual-tasking in individuals under 60 years of age. Our main hypothesis is that individuals with DPN will have more deficits than individuals with diabetes. These last ones will also show deficits compared with healthy individuals.

METHODS

The study is cross-sectional observational research that involved 55 adults, with a mean age of 47 years, where 51% are men, divided into three groups: diabetes (DG), diabetic peripheral neuropathy (DPN), and a healthy control group (CG). Data were collected from September 2022 to September 2023 at two locations in Manaus, Amazonas: the Magdalena Arce Daou Family Living Centre for the diabetic groups and the Faculty of Physical Education and Physiotherapy at the Federal University of Amazonas (UFAM) for the control group.

Participant selection criteria

The diabetic groups were included based on the following criteria: (1) age 18 to 59 years, (2) ability to walk independently without the use of walking aids, (3) any plantar ulceration must have been healed for at least six months; (4) a score of more than 1 out of 10 for the physical assessment of the MNSI instrument for the DPN group and a score of less than 1 out of 10 for the DG and CG groups; (5) must not be receiving any physiotherapeutic intervention at the time of the assessment. Healthy control participants were recruited through online advertising and word of mouth at UFAM. Inclusion criteria were as follows: (1) age 18 to 59 years, (2) absence of diabetes, and (3) meeting the inclusion criteria required for the participants with diabetes. The exclusion criteria included: (1) individuals over the age of 60; (2) the need for a walking aid; (3) history of vestibulopathy, retinopathy, nephropathy, neurological disease (poliomyelitis, stroke, cerebellar ataxia, Parkinson's disease) or orthopaedic disease (fracture, knee or hip prosthesis, congenital diseases such as congenital clubfoot); (4) Charcot's arthropathy confirmed by X-ray; (5) the presence of plantar ulcers at the time of assessment or claudication of any aetiology.

The Human Research Ethics Committee of the Federal University of Amazonas approved this study under the protocol number 4.840.390 and CAAE 48610921.5.0000.5020. All participants signed an informed consent form consent.

Initial Assessment

It consisted of investigating aspects related to the presence of diabetes and DPN, with an inspection of the feet using the Michigan Neuropathy Screening Instrument questionnaire (MNSI-q)[10]. An experienced physiotherapist carried out the physical examination of the feet, which included assessing the appearance of the feet, the presence of ulceration, the Achilles reflex, perception of vibration in the Hallux (128 Hz tuning fork), and tactile sensitivity to the 10g Semmes-Weinstein monofilament in the hallux[11].

Assessment of Cognitive and Functional Physical Performance

It consisted of the following tests: Montreal Cognitive Assessment (MoCA) questionnaire, Timed up and go (TUG), Timed up and go with a dual task (TUGWDT), and the gait speed test (10-meter). The MoCA is a test for cognitive screening that has been applied to identify patients with mild cognitive impairment[12]. The TUG is the time taken to stand up from sitting (with the back straight and the feet resting on a flat surface positioned around shoulder width, arms crossed at chest height, with hip and knee flexion of approximately 90°, chair seat height: 43 cm); move to a cone at ≅2.45 m, go around it and return to the sitting position as quickly as possible[13].

The dual-task TUG (TUGWDT) is identical to the TUG[14], but the subjects performed calculations (subtractions) during the test: serial subtractions of 3 (100-3; 97-3; 94-3) starting with different numbers on each attempt. The average time of the three attempts was used for analysis. The cost of the dual task was calculated using the formula: performance of the isolated task (in seconds) subtracted by the performance of the task with DT (in seconds), divided by the performance of the isolated task multiplied by 100[15].

For the gait speed test, the individual was asked to walk 10 meters at their usual speed during 3 valid attempts, with 1 test for familiarisation[16]. A decreased gait speed was considered to be less than 0.8 meters/second[16-18]. The time of the three valid attempts was recorded, taking into account the start of the movement, the first movement of the phase of removal of the calcaneus from the ground until the last contact with the foot at the end of the 10 meters[19].

The functional tests with and without dual tasks were analysed using an accelerometer, controlled by a biomechanical analysis program called "G-STUDIO" to identify possible changes in spatial-temporal variables of the gait. To perform the 10-meter gait speed test, the participants had the device positioned in the S1-S2 intervertebral space and were instructed to walk at their usual, comfortable pace. To perform the TUG and TUGWDT, the participants must had the device positioned in the height of L2 intervertebral space.

Data analysis

Continuous variables were reported as mean and standard deviation. Normality and homoscedasticity for the results in all measures were assessed with the Shapiro-Wilk and Levene tests, respectively. An alpha level of 5% was adopted to determine statistical significance ($p \leqslant 0.05$). A one-way ANOVA test and Tukey's post-hoc test were carried out for continuous variables, while the Dwass-Steel-Critchlol-Flinger test was used for non-ordinal and ordinal nominal variables. All statistical procedures were carried out using JAMOVI software version 2.3.28 for Windows 10.

RESULTS

This study included 20 individuals with diabetes without neuropathy (DG), 15 individuals with diabetic neuropathy (DNP), and 20 health controls (CG). The sociodemographic and anthropometric characteristics of the population are listed in Table 1, while Table 2 shows the data from the functional tests carried out on the population.

Table 1. Mean (± standard deviation) of sociodemographic characteristics of groups CG, DG and DNG.

Variables	CG (n = 20)	DG (n = 20)	DNG (n = 15)	p-value
Age (years)	45.10 ± 9.08	47.35 ± 7.78	50.67 ± 7.08	0.143[1]
Sex (number of men, %)	12 (60)	8 (40)	8 (53)	0.438[2]
Height (m)	1.69 ± 0.09	1.63 ± 0.11	1.63 ± 0.09	0.125[1]
BMI (kg/m²)	28.19 ± 5.06	29.76 ± 5.62	30.32 ± 7.80	0.555[1]
Physical activity level[3] (n, %)	14 (70)	4 (20)	4 (20)	0.003[2]
Educational level (%)				
0-8 years (n, %)	-	4 (20)	0 (0)	0.004[2]
9 years (n, %)	5 (25)	10 (50)	7 (47)	0.004[2]
10-11 years (n, %)	1 (5)	2 (10)	4 (27)	0.004[2]
12-18 years (n, %)	14 (70)	3 (20)	4(27)	0.004[2]

Note: [1]ANOVA one-way test, [2]Chi-squared test. [3]Minimum of 150 minutes/week according to the American College of Sports Medicine.

Table 2. Mean (± standard deviation) of the functional tests and cost of dual-tasking (DT) of the groups CG, DG and DNG.

Variables	CG (n = 20)	DG (n = 20)	DNG (n = 15)	p-value
MoCA (score)	23.6 ± 3.40	19.8 ± 5.0*	26.46 ± 3.22	0,013[1]
Gait speed test (m/s)	1.27 ± 0.17*	0.99 ± 0.20*&	0.82 ± 0.20*&	<0,001[1]
TUG (s)	7.45 ± 1.53*	9.66 ± 1.22*&	11.91 ± 1.83*&	<0,001[1]
TUGWDT (s)	9.51 ± 1.77*	11.48 ± 1.20&	14.85 ± 2.48*&	<0,001[1]
Coust of DT of TUGWDT (%)	28.6 ± 11.10*	19.1 ± 5.71&	24.9 ± 10.20	0,009[1]

Note: [1]Test ANOVA, *&Post-hoc de Tukey (represents the statistical difference between groups).

The Montreal Cognitive Assessment (MoCA) questionnaire has a maximum score of 30 points, and a score of 26 or more is considered normal. The group of people with diabetes (DG) had a significantly lower average score on the test (19.8±5.0, p=0.013) compared to the CG (23.6±3.4) and DNG (26.46±3.22). In the gait speed test, the healthy control group (CG) had a significantly higher average speed (1.27±0.17, p<0.001) compared to DG (0.99±0.2) and DNG (0.82±0.2), while DG had a higher average speed (0.99±0.2, p<0.001) compared to DNG (0.82±0.2).

In the Timed Up and Go test (TUG), the DNG had a higher average time to complete the test (11.91 ± 1.83, p<0.001, table 2) compared to the CG (7.45±1.53) and DG (9.66±1.22) groups. In addition, the DG group had a longer TUG execution time than the CG.

Similar behaviour of TUG was observed between the groups in the TUGWDT, table 2. The DNG (14.85 ± 2.48, p<0.001) had a longer execution time compared to the DG (11.48±1.25) and CG (9.51±1.77) groups, in the same direction DG was slower compared to CG. When analyzing the cost of dual-task TUGWDT, the CG group (28.6±11.1) had a significantly higher cost compared to DG (19.1±5.71; p=0.009). Thus, DT increased the time required to complete the TUGWDT tests in all groups (27.7% in CG, 18.8% in DG, and 24.7% in DNG).

The individuals with diabetic peripheral neuropathy had slower gait speeds than those without neuropathy (17% lower) and healthy controls (35% lower). Diabetes alone also reduced gait speed compared to healthy individuals (22% lower).

DISCUSSION

The study aimed to examine how diabetes, diabetic peripheral neuropathy, and dual-tasking affect gait speed in individuals under 60 years of age, with and without type 2 diabetes, compared to healthy controls.

The results show that individuals with DPN had a lower gait speed (0.99±0.2 m/s), 35% lower than the normal speed of 1.53 m/s reported in the literature[20]. Reduced strength significantly impairs locomotor performance, and recent studies have shown lower gait speeds in individuals with diabetic neuropathy compared to healthy peers[21].

The group with DPN presented a longer time to perform the TUG and TUGWDT compared to individuals with diabetes and healthy individuals. These results corroborate the findings described in the literature on diabetic neuropathy, in which individuals diagnosed with this disease have serious adverse health conditions that reduce their quality of life (1) since they have reduced distal sensitivity of the upper and lower limbs[22]. They walk slowly and take shorter steps, their stride width is greater and they spend more time during the gait cycle in simple support and double support[23].

Therefore, altered human gait is the product of disorders in global motor skills, proprioception, balance, and cognition, and is quite complex since when we walk, for example, we perform dual tasks, such as talking on the phone or carrying bags[24,25]. DG had a longer execution time of TUG and TUGWDT compared to healthy individuals. In other words, even in the absence of neuropathy, diabetes has an impact on these people's activities of daily living.

To discuss the influence of dual-tasking, we need to understand cognitive-motor interference, which refers to the moment when the execution of a cognitive and motor task results in a percentage variation in the performance of one or both activities[26]. This fact explains the increase in the cost of the dual task in the CG individuals, who had a higher level of education, which favoured increased concern about getting the calculations right while performing the tests, generating a higher cost of the dual task.

The DG had a lower average score on the MoCa test compared to CG and DNG, and most of the individuals had a lower level of education than the other groups. The literature points out that better performance in cognitive tests is expected in individuals with a higher level of education, as in addition to providing cognitive reserve[27], educational level is considered a parameter for establishing normative data[28].

The difference in the educational level of the groups may be a factor that contributed to the lower performance on the MoCA, but individuals with type 2 diabetes have a higher risk of developing cognitive deficits, which can range from mild cognitive impairment to dementia[29].

This study investigated the effects of dual-tasking on the functional performance of individuals with diabetes and diabetic peripheral neuropathy in adults under the age of 60 years, highlighting the interaction between cognition and locomotion. The results showed that both diabetes and neuropathy negatively impact gait speed and functional test execution time, even in the absence of neuropathy.

CONCLUSION

The study found that diabetes and its complications notably affect motor and dual-tasking performances. Individuals with DPN took longer on the Timed Up and Go test compared to those with non-neuropathic diabetes and healthy controls. Diabetes and neuropathy reduce walking speed and increase the time to complete the Timed Up and Go Test, especially when dual-tasking is required. This highlights the possible need for physical and cognitive interventions to improve patient quality of life.

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