Comparison of spatiotemporal parameters between simple and dual task gait in dementia

Vlotinou P.[1], Aggeloussis N.[2], Vadikolias K.[1] Giannakou E.[2], Terzoudi Aik[1]., Piperidou X[1]., Heliopoulos I[1].
[1]University Department of Neurology, General Hospital of Evros
[2] Democritus University of Thrace, Department of Physical Education and Sport Science, Komotini
nagelous@phyed.duth.gr

Abstract

The present study determines the changes in the spatial and temporal parameters of gait, in patients with dementia, under four conditions, the simple gait, the gait under a simple and complex kinetic goal and the gait under the influence of a cognitive target. 17 participants, diagnosed with Alzheimer's dementia disease, (MMSE score:16-23/30) were evaluated and underwent gait analysis through a system of biomechanical analysis and a variance analysis for repeated measurements was applied for the statistical analysis.
The results of gait analysis, showed that the gait speed as well as the frequency of the gait, showed significantly lower values when gait was performed under dual cognitive task, than in the other three conditions. On the other hand, stride length as well as step length, remained unaffected by the type of gait task. During dual cognitive task gait: pitch duration, duration of single and double leg support, were increased. The speed of walking and the frequency of walking, of dementia patients showed significantly lower values during walking with a double cognitive target relative to the other three conditions.

Introduction

Dementia is a neurodegenerative disease, characterized by cognitive and motor skills impairment. The gradual deterioration of the disease is accompanied by a decline in memory, judgment ability, spatial and temporal orientation and a limitation in motor planning and skills, such as balance and coordination, skills inextricably linked with the gait of the patient. The gait mechanism is significantly affected by dementia and is burdened by internal factors such as the speed of progression of the disease as well as by external environmental factors such as target requirements (simple or walking under dual task) (Sheridan, Solomont, Kowall, Hausdorff, 2003). Gait evaluation in demented patients may be an important field for prognosis and prediction of disease outcome (van Lersen, Hoefsloot, Munneke, Bloem, Olde Rikkert, 2004; Verghese, Lipton, Hall, Kuslansky, Katz, Buschke, 2002).

The evaluation of gait in people with dementia, primarily performed through clinical observation, self-reference, execution of neurological tests and secondarily, through the evaluation with quantitative tools such as gait analysis, which is a valid and reliable tool (Pfister, West, Bronner, Noah, 2014). The parameters of gait affected by dementia include spatial and temporal parameters such as gait speed, frequency, step length, stride length, step time, single and double support time (Cullen et al., 2018).

Patients with dementia, are considered to walk with reduced gait speed and step length compared to healthy peers, while the diversity of the gait process is increased (Kenny, Richardson, Steen, McKeith, Shaw, 2000; Merory, Wittwer, Rowe, Webster, 2007). According to Gillain, et al. (2016), during simple walking, in patients with cognitive deficits not only the gait speed but also the symmetry and the frequency of gait are affected (Gillain, Drame, Lekeu, Wojtasik, Ricour, Salmon, 2016). In case that the requirements of the external environment are increased by an additional task during walking, a cognitive task (e.g. walking and talking) or kinetic task (e.g. to walk while retaining something in the upper extremities), walking parameters are negatively affected.

Gait and cognition seems to be “communicating vessels”, so the burden of the second reflects the functionality of the first, which should be taken into account when organizing and implementing maintenance programs of patients ' skills (Hausdorff, Schweiger, Herman, Yogev-Seligmann, 2008).

Petterson, Olsson and Wahlund (2007), determined the negative effect of dual task on gait speed in dementia patients (Petterson, Ollson, Wahlund, 2007). The researchers Takehiko, et al., (2016) argued that the addition of a cognitive task in patients gait, increases the requirements and the burden for the person walking, reducing the speed, step length and gait rhythm in transverse and frontal level analysis (Takehito et al., 2016). Holman and Kovash (2007) also concluded that as the gait speed decreases, the variability of the gait pattern in each gait cycle expands (Hollman, Kovash, Kubik, Rachel, 2007). Smith, Cusack and Blake (2016), further investigated the effect of the target type on gait speed, using as a second target the verbal eloquence and found that the speed was reduced by 0.19 m/sec-1.02 m/sec (Smith, Cusack &Blake, 2016). In addition, it was found that the complexity of the target intervened negatively in the frequency, stride time and reproducibility of the gait (Smith, Cusack &Blake, 2016). Wittwer, Webster and Hill focused on the effect of a dual gait task on demented patients, that concerned only a second motor rather than a cognitive task. Their research found that gait speed and step length decreased statistically significantly, while gait variability increased significantly under the influence of a kinetic target (Wittwer, Webster, Hill, 2016). It is therefore important to consider changes in spatial-temporal parameters of gait both in simple and dual task gait (under cognitive but also kinetic task), not only because of the lack of sufficient number of studies, especially for the effect of the motor target, but mainly due to the value of the above information in diagnosing dementia patients and designing analytical programs to enhance their skills.

The purpose of this research is to investigate the change in spatial temporal parameters (gait frequency, stride duration, step time, duration of single and double support, stride length and pitch, gait speed) when a patient with dementia walks under different conditions (simple gait and walking under dual task, motor or cognitive).

The main research hypothesis is that a cognitive task during gait, will cause a more significant change in the spatial parameters of gait, related to the changes caused during simple gait or under the addition of a kinetic task.

Methodology

Participants

The survey involved 20 men and women with an age 72.9 ± 2 years who met as a criterion for diagnosis, Alzheimer's dementia, and were diagnosed in the outpatient clinics of dementia, the University neurological Clinic of the peripheral general Hospital of Evros, or participated in the "Memory School", external structure of the university neurological Clinic. The admission criteria were defined as the possibility of transition to the laboratory of Biomechanics of the Department of Physical Education and Sport science, the lack of a sensory, orthopedic problem or other nature of a disease condition that could affect and limits the gait, the ability to understand and execute commands. Patients with no independent gait (< 100m) and severe psychiatric illness were excluded from the investigation. The patients were involved in written consent of the same or carers who held the right to act instead of them and could withdraw at any time they wished it from the investigation. The research took place after acceptance by the Scientific Council of the University General Hospital of Evros.

Gait Analysis

Patients gait was evaluated through a system of biomechanical analysis (Vicon), consisting of 6 cameras (100 images/sec), 2 piezoelectric dynamos (Kistler), Dimensions 60 X40cm, for the recording of reaction forces of the ground for each leg, with a frequency of 1000Hz. The cameras were placed around a 12-metre walk corridor in the middle of which the two power floors were packed.

Performance of gait analysis

The examined patients were dressed with adjustable garments, keeping the lower limbs uncovered from the height of the mildness of the thigh. The procedure was initially explained, and their basic somatic metrics were recorded. Self-adhesive reflectors were placed at specific anatomical points of the lower extremities and pelvis and especially over (the second metatarsal bone, the heel, the lateral malleolus, the middle of the tibia, the lateral femoral epicondyle, the thigh, the anterior superior iliac spine and the posterior superior iliac spine, to each side of the body).

The patients performed 5 gait attempts to get familiar to the gait analysis procedure and then they were asked to walk under their physical gait speed. In order to achieve the retention of speed, the subjects walked by following a moving rod, the speed of which was adjusted to coincide with the natural gait speed of each patient. During the main experiment, each of the patients, performed a sufficient number of simple gait attempts in order to achieve 10 valid repetitions,

Subsequently, the gait of each examined person, was evaluated in the same way. Under simple walking, under a simultaneous cognitive objective which included the recall and the narration of objects belonging to one of the categories: colours, clothes, fruit-vegetables, animals, under a kinetic target, which involved the transfer of a disc with an empty glass in the center, using the dominant limb and the elbow in flexion at an angle of 90^0 and finally, under a simple kinetic task, with the patient having the elbow of the dominant limb at an angle of 90^o.

Data collection and analysis

A gait analysis system was used, using Nexus software (Vicon) to record the moments of heel landing and take-off time. For the analysis of the above data and for calculating the temporal phase of gait and the special- temporal parameters, Polygon software (Vicon) was used.

The calculated spatio-temporal parameters were: stride length (m), step length (m), gait speed (m / sec), gait frequency (steps / minute), stride time (sec), step time (sec) double support time (sec) and single support time(sec).

For the statistical analysis of these variables, it was applied an analysis of variance for repeated measures. "Gait condition" was set as the repetition factor (simple walking, walking under a simple kinetic task, complex kinetic task and cognitive task) and the two lower extremities, (right, left). For multiple comparison test, Bonferroni test was performed, and the significance level was determined as $p <.05$.

Results

Only 15 of the 20 subjects completed the total process of gait analysis and therefore the spatiotemporal gait parameters were calculated from the data of 15 patients.

Gait Frequency

No statistically significant interaction was found between the gait condition and the lower limb ($F_{3, 33}$ = 0.710, p =. 553, n^2 =. 061). On the contrary, there was a statistically significant main effect of the gait condition ($F_{3, 33}$ = 28,422, p <. 001, n^2 =. 721). Bonferroni comparison's test showed that the subjects during gait with cognitive target had significantly lower gait frequency (p <. 001) than in the other three conditions (Figure 1).

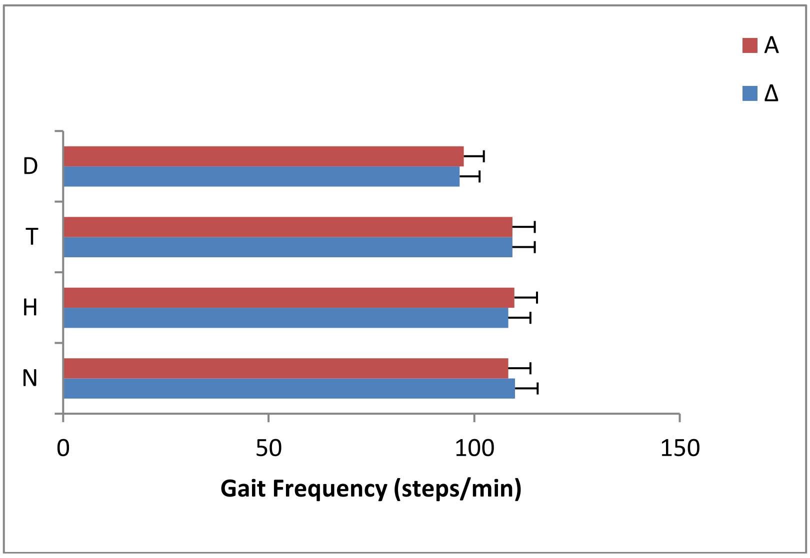

Figure1. Averages (standard deviations) of the frequency of gait of patients in the four conditions (N: Simple gait, H: gait with simple kinetic task, T: gait with complex kinetic task, D: gait with cognitive task), in the two lower extremities (d: Right, A: left)

Stride Time

There was no statistically significant interaction between gait condition and the lower limb ($F_{3,\ 33}$ = 0.634, p =. 598, n^2 =. 054). However, there was statistically significant major effect of the gait condition factor ($F_{3,\ 33}$ = 27,017, p <. 001, n^2 =. 711). The multi-comparison test Bonferroni found that the stride time was significantly higher (P <. 001) in gait with cognitive task than in the other three conditions (Figure 2).

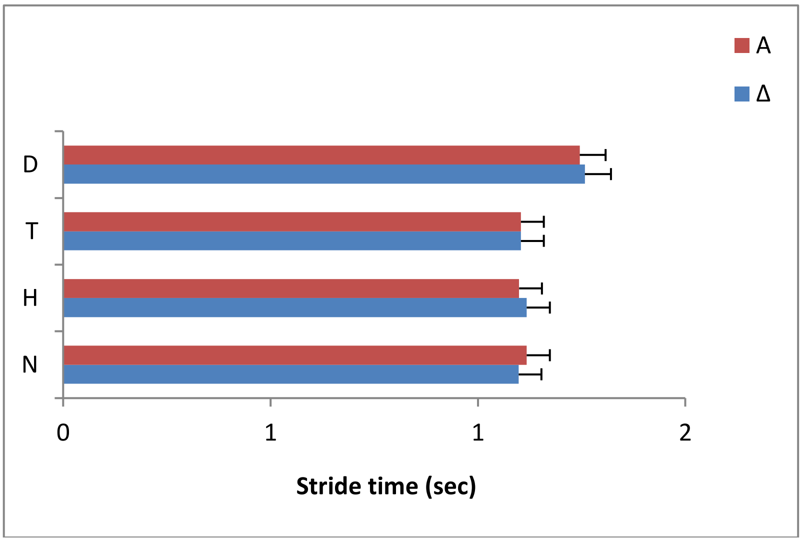

Figure 2. Averages (standard deviations) of the patient stride time in the four conditions (N: Simple gait, H: gait with simple kinetic task, T: gait with complex kinetic task, D: gait with cognitive task), at the two lower extremities (d: Right, A: left).

Step time

There was no statistically significant interaction of the gait condition with the lower limb ($F_{3, 33}$ = 0.760, p =. 525, n^2 =. 065). Instead there was statistically significant major effect of the condition factor ($F_{3, 33}$ = 32,087, p <. 001, n^2 =. 745). Bonferroni multiple comparison test found that the step time was significantly higher (p <. 001) in gait with cognitive task than in the other three conditions (Figure 3).

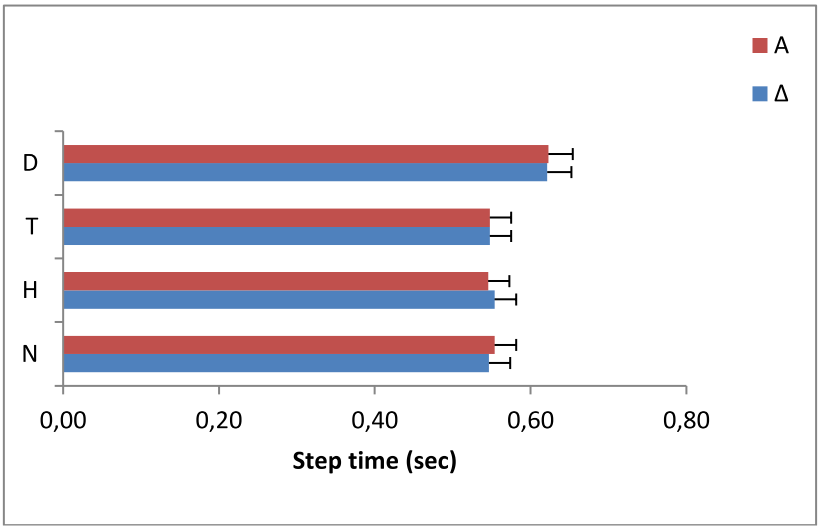

Figure 3. Averages (standard deviations) of the patient's step time under the four conditions (N: Simple gait, H: gait with simple kinetic task, T: gait with complex kinetic task, D: gait with cognitive task), at the two lower extremities (d: Right, A: left).

Single support time

No statistically significant interaction of the gait condition with the lower limb was found ($F_{3, 33}$ = 2,173, p =. 087, n^2 =. 284). Instead there was statistically significant major effect of the condition factor ($F_{3, 33}$ = 17,174, p <. 001, n^2 =. 682). From the multiple comparison Bonferroni test, it was found that the duration of single support time of each lower limb was significantly higher (p <. 001) under gait with cognitive task than in the other three conditions (Figure 4).

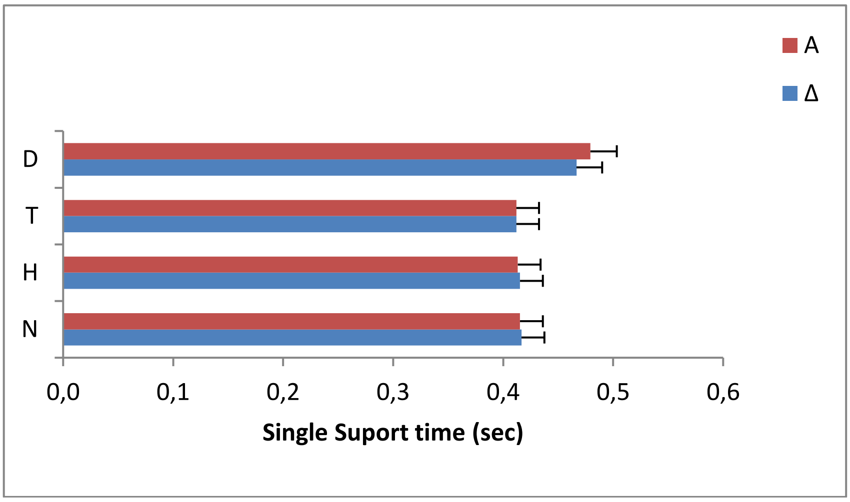

Figure 4. Averages (standard deviations) of the duration of a single support time for patient gait under the four conditions (N: Simple gait, H: gait with simple kinetic task, T: gait with complex kinetic task, D: gait with cognitive task), at the two lower extremities (d: Right, A: left).

Double support time

The results found that there was no statistically significant interaction between the gait condition and the lower limb ($F_{3, 33} = 2.001$, p =. 145, n^2 =. 222). Instead there was statistically significant major effect of the condition factor ($F_{3, 33}$ = 23,845, p <. 001, n^2 =. 773). Bonferroni test, found that the duration of double support of each lower limb was significantly greater (P <. 001) in gait with cognitive task than in the other three conditions (Figure 5).

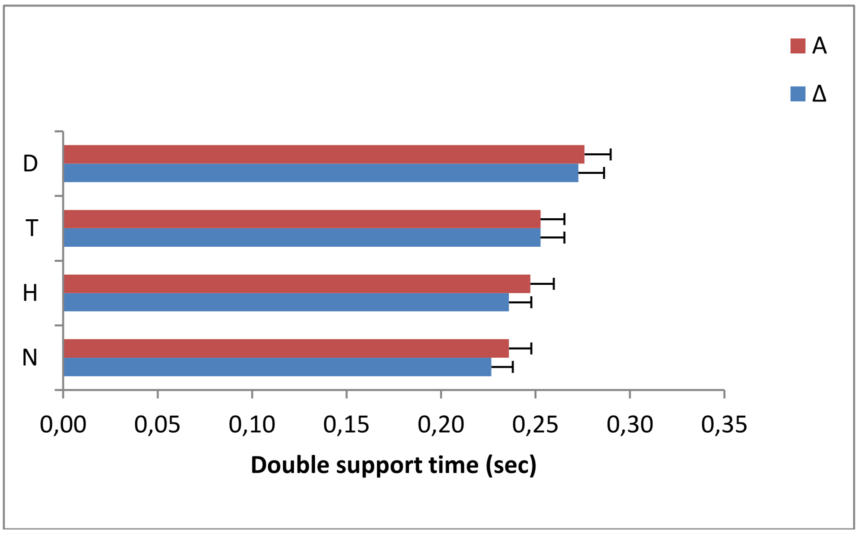

Figure 5. Averages (standard deviations) of double support time for patient gait during the four conditions (N: Simple gait, H: gait with simple kinetic task, T: gait with complex kinetic task, D: gait with cognitive task), at the two lower extremities (d: Right, A: left) .

Stride Length

No statistically significant interaction between the gait condition and the lower limb ($F_{3,\ 33}$ = 3.112, p =. 062, n^2=. 237). There was also no statistically significant main effect of the condition factor ($F_{3,\ 33}$ = 0,291, p =. 831, n^2 =. 026). Therefore, no significant differences in stride length between the four different gait conditions were found (Figure 6).

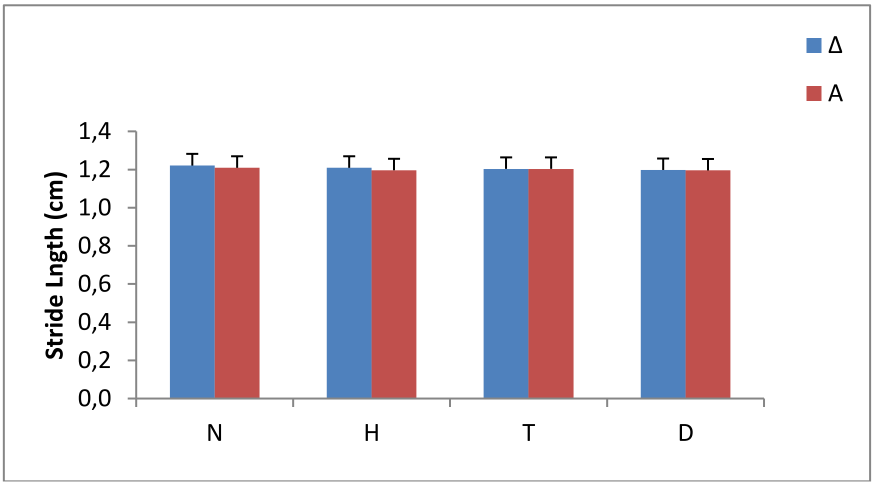

Figure 6. Averages (standard deviations) of the patient stride length in four conditions (N: Simple gait, H: gait with simple kinetic task, T: gait with complex kinetic task, D: gait with cognitive task), in the two lower extremities (d: Right, A: left).

Step length

There were no statistically significant differences between the gait condition and the lower limb ($F_{3,\ 33}$ = 1,060, p =. 327, n^2 =. 096). There was also no statistically significant main effect of the condition factor ($F_{3,\ 33}$ = 0,197, p =. 898, n^2 =. 018). Therefore, the gait condition did not significantly affect the length of the step (Figure 7).

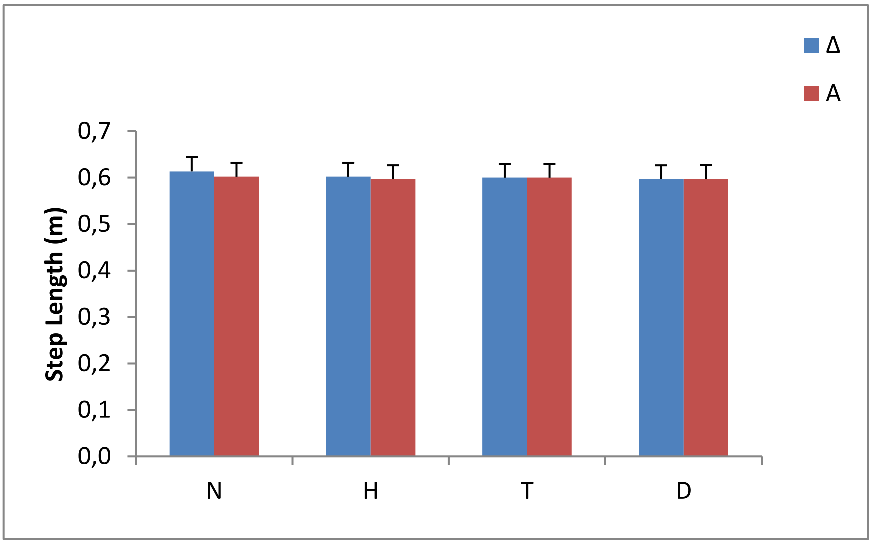

Figure 7. Averages (standard deviations) of the patient walking pitch length in the four conditions (N: Normal Gait, H: gait withsimple mobile target, T: gait kinematic composite target, D: gait with known target), at the two lower ends (A: right side A: left).

Gait speed

There was no statistically significant interaction of the gait condition with the lower limb ($F_{3,\ 33}$ = 2.595, p =. 071., n^2 =. 206). On the contrary, statistically significant major effect of the condition factor was found ($F_{3,\ 33}$ = 20,570, p<. 001, n^2 =. 652). From Bonferroni multiple comparison test, was found that gait speed was significantly lower (p <. 001) during gait with cognitive task than in the other three conditions (Figure 8).

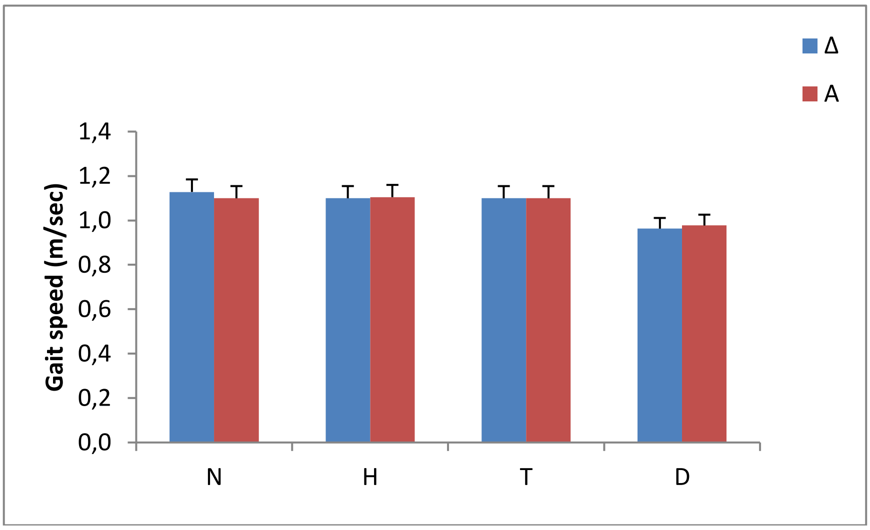

Figure 8. Averages (standard deviations) of gait speed of patients in the four conditions (N: Simple gait, H: gait with simple kinetic task, T: gait with complex kinetic task, D: gait with cognitive task), at the two lower extremities (d: Right, A: left).

Discussion

From the results of our research, the basic hypothesis was fully confirmed for the whole gait parameters (duration of stride, duration of step, duration of single and double support), which had significantly higher values in gait with a cognitive task. In contrast, no significant differences were found between gait with cognitive task and the remaining three conditions in spatial parameters (stride length and step length). As a result, the research hypothesis was fully confirmed for the combined spatial temporal parameters (gait frequency and gait velocity), which were significantly lower in gait with a simultaneous cognitive target. In particular, it was found that the effect of a second task, during the gait of patients with Alzheimer's dementia, degrades the functionality of gait, making it difficult to perform effectively, especially when the second task is a cognitive goal. The parameters which are significantly affected are the temporal parameters, the increase of which led to a decrease in the gait frequency and in combination with the non-alteration of the spatial parameters, in a reduction of the gait speed.

The time durations of the single and double support, which affect the duration of the step and stride respectively, are significantly related to the ability of the dynamic equilibrium of the person walking, and particularly to the extent to which it maintains its stability during the single support. Maintaining balance during gait is a complex neural function that involves the treatment of sensory exogenous and endogenous information and the production of optimal muscle synergies in order to maintain the body's center of mass, near the point of application of the ground reaction force during the single support. The addition of a second cognitive task, acts as an "overload", of the already existing cognitive-kinetic goal of gait, resulting in the reduction of the ability for balance and the increase in spatial parameters of gait. On the contrary, the spatial parameters of gait are influenced by the strength of the lower extremities, the production of which has fewer requirements at a nervous level, in relation to the preservation of equilibrium. Therefore, the "overload" of the already existing cognitive-kinetic goal of gait with the simultaneous addition of another cognitive goal, did not significantly affect the production of power and did not significantly change the length of step and stride during walking. In addition, from the two spatial temporal parameters, the reduction of the gait frequency with the addition of a second cognitive task is related to the increase in the duration of each step, and the decrease of the gait speed, was the result of the non-change in stride length and the increase of stride duration.

The effect of a second cognitive task on gait has conflicting results in terms of stride time in studies by other researchers. Montero-Odasso, Muir & Speechley as well as Choi et al., found an increase in stride time while Nascimbeni et al., did not detect statistically significant differences in stride time and gait with a double cognitive task (Montero-Odasso, Muir & Speechley. 2012; Choi et al.,2011; Nascimbeni, et al. 2015). However, in the above research, significant differences were found in stride time during the most "burdened" by the cognitive targets used, the gradual removal of 7 numbers in relation to the naming of animals in elderly with mild cognitive impairment. With regard to the duration of the double and single leg support, Cedervall, Havorsen and Aberg (2014), found that it is statistically significant higher, when walking under a dual cognitive task, a finding corresponding to the present investigation (Cedervall, Havorsen and Aberg, 2014).

On the other hand, there are conflicting results concerning the effect of a second task on the step length. Gillain et al., (2009), Rucco et al., (2017) and Verghese et al. (2008), found a significant effect of the double cognitive task in gait performance, showing a reduction in step length, opposed to Maquet et al. (2010), who did not find a significant effect of the double cognitive task on step length in patients with Alzheimer's dementia (Gillain et al., 2009; Rucco et al., 2017; Verghese et al., 2008; Maquet et al., 2010).

Smith, Cusack & Mlake, in their research, noted that the effect of a second cognitive target significantly reduces gait speed, even in healthy elderly people (Smith, Cusack & Mlake, 2016). Respectively, Borges, Radanovic et Forlenza, referred to the effect of "shared attention" on the performance of a cognitive goal, highlighting the impact of multiple cognitive objectives at the expense of the quality of the movement, regarding the speed and gait frequency (Borges, Radanovic, Forlenza, 2015). The dual cognitive task in walking, in elderly people who exhibit memory difficulties and cognitive deficits, results in an adaptation difficulty, to follow the increased needs of the task, loss of balance and risk of falling. Also, Rucco, et al., found that the speed in the execution of a dual cognitive task in Alzheimer's patients, is statistically significantly lower than other walking conditions (simple gait, walking with a kinetic target) (Rucco, et al., 2017). On the other hand, the parameter of gait frequency also appears to be statistically significantly lower in the execution of a dual cognitive task, accordingly to Belgali, Chastan, Cignetti, Davenne & Decker (Belgali, Chastan, Cignetti, Davenne & Decker, 2017).

The results of this research can be used to assess the progression of disorders in dementia patients and to plan intervention programs to delay the gait decline. In fact, according to Montero-Odasso et al., the control of simple gait by speed, in patients on the threshold of cognitive disturbance, is not a safe means of assessing such progress, as opposed to evaluation through gait with dual task (Montero-Odasso et al., 2017). Furthermore, the creation of interventional programs based on the findings of the present research and relevant research protocols may help patients with dementia to maintain gait skills for a longer period of time, contributing in the short term to maintaining their operational level and independence.

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