Impact of Dual Task on Parkinson's Disease, Stroke and Ataxia Patients' Gait: A Comparative Analysis

Impacto da Dupla Tarefa na Marcha de Pacientes com Doença de Parkinson, Acidente Vascular Cerebral e Ataxia: Uma Análise Comparativa

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Abstract

Introduction: Performing dual task for neurological patients is complex and it can be influenced by the localization of the neurological lesion. Objective: Comparing the impact of dual task on gait in patients with Parkinson's disease, stroke and ataxia. Method: Subjects with Parkinson's disease (PD) in initial phase, stroke and ataxia, with independent gait, were evaluated while doing simple gait, with cognitive, motor and cognitive-motor gait demand, assessing average speed and number of steps. Results: Ataxia and stroke patients, compared with PD, showed an increase in the number of steps and decrease the average speed on the march with cognitive demand. Subjects with PD performed better on tasks when compared to others. Conclusion: In this study the impact of dual task was lower in Parkinson's disease patients.

Keywords: Gait, locomotion, physiotherapy, hemiplegia, dual task.

Resumo

Introdução: A realização de dupla tarefa para pacientes neurológicos é considerada complexa e pode ser determinada pela topografia da lesão neurológica. Objetivo: Comparar o impacto da dupla tarefa na marcha de pacientes com Doença de Parkinson em fase inicial (DP), Acidente Vascular Cerebral(AVC) e Ataxia. Método: Sujeitos com DP em fase inicial, AVC e Ataxia cerebelar, com marcha independente, foram avaliados realizando marcha simples, com demanda cognitiva, com demanda motora e com demanda cognitivo-motora, mensurando-se velocidade média e número de passos. Resultados: Os atáxicos e AVE comparados com os DP, apresentaram aumento do número de passos e diminuição da velocidade média na marcha com demanda cognitiva. Os sujeitos com DP apresentaram melhor desempenho nas tarefas comparados aos demais. Conclusão: O impacto da dupla tarefa apresentou-se menor nos pacientes com DP.

Palavras-chave: Marcha, locomoção, fisioterapia, hemiparesia, dupla tarefa.

The performance of dual task is also known as simultaneous performance and it involves a primary task performance, which is the mainly focus of attention, and a secondary task, executed at the same time (O'Shea, Morris, & Iansek, 2002). In normally circumstances, carrying out motor and cognitive tasks is common, and the ability of the subjects for performing both tasks at the same time is a pre requirement to a normal lif (Teixeira & Alouche, 2007).

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According to the recruitment of encephalic areas, during the functional activities which are connected or not to secondary tasks, the cerebral cortex is such required during the information processing, because when the movements become automatized, they start occurring in subcortical areas, as the basal ganglia, cerebellum and thalamus, and the cortical area becomes free to process more complex information. Though, when primary tasks are automatized, there is no need to direct the attention for a primary movement (in this case, gait), allowing secondary tasks to be done in association with motor and cognitive demand. In a neurological patient, the automatized movements are damaged and it may appear the impact of dual tasks, reverberating on daily activities (Bond & Morris, 2000). This damage may be influenced

by the local of the lesion, considering the cortical, subcortical and cerebellar areas.

The gait is a ritmic behavior, which is automatic. It is generated mainly for subcortical systems. So that, it is performed with no attentive focus (with exception in the acceleration and desacceleration phases; Kandel, Schwartz, & Jessel, 1997). However, even walking is impaired when performed in conjunction with another task, which suggests the existence of an interference caused by competition for attentional resources that would involve levels of cortical control for the gait (Beauchet & Berrut, 2006).

After a brain injury, some people might show difficulties for performing motor and cognitive skills, because a high level of information is observed during the execution of both tasks at the same time, resulting in a damaged performance of one of them or both (Caldas, 2000; Wu & Hallet, 2008).

Damages on the performance of primary or secondary tasks with motor or cognitive demand might become an important indicator of the patient`s state functions. This alteration is normally named as motor cognitive interference and after a brain injury the previously automatized activities require a controlled process with an increase of attention demand, leading to damages during the dual task (Haggard, Cockbum, Cock, Fordham, & Wade, 2000). According to Yea-Ru, Yu-Chung, Chun-Shou, Shih-Jung and Ray-Yau (2006), neurological injury can be more impacting on dual tasks performances than the own aging effect, once for individuals with any neurological injury the act of doing two different tasks simultaneously causes worse performance when comparing to healthy elderly.

With the development of neuroimaging techniques, studies were carried out to elucidate the neuroanatomical and / or neurophysiological causes for dual task performances. Thus, Wu and Hallett (2008) carried out a study with Parkinson's disease subjetcts to demonstrate changes in cortical activation patterns involved in automaticity of movements during dual task (motor and cognitive task demands). With respect to the groups (control and experimental) patients had greater activation of prefrontal dorsolateral cortex, medial frontal gyrus, bilateral premotor area, bilateral parietal cortex, bilateral temporal lobe, occipital lobe, cerebellum, thalamus and cingulate gyrus compared with the same areas in healthy subjects while performing dual tasks. There was greater activation in precuneus bilaterally when performing the dual task, and more than that, there was activation of bilateral parietal cortex, premotor area, inferior frontal gyrus, supplementary motor area, basal ganglia and cerebellum. The authors showed that there was no difference in the activation of the image with respect to the type of concurrent task. However, patients with Parkinson's disease recruited more cortical reserves as compared to the control group. According to the authors when they perform more complex tasks there is a limited capacities which were exceeded in patients, which meant that they could not perform the same tasks correctly, featuring an existence of a dual-task interference.

In this context, injuries in cortical or subcortical areas may reverberate in different ways on performance of dual tasks and shocked in a peculiar form depending on neurological injury area. Besides, the demand of secondary task can be a factor which might interfere on performance, both primary and secondary tasks in patients with different injured areas and these studies are not available in the literature until the present moment.

The mainly purpose of this study was to investigate the impact of dual task on gait in patients with different injured areas as Parkinson Disease (PD), stroke and ataxia. As a secondary objective, this present study intended to investigate the effect of the type of demand of the secondary task (motor, cognitive and associated) on the gait performance in those patients. These results might clarify the impact of the local of the lesion on the dual task performance and provide some insights to the rehabilitation of the different groups involved.

Materials and Method

Place

This study was approved by the Ethic Committee of the Institution (13383410), respecting the ethics aspects according to the Resolution nº 196 of October 10, 1996, that delimits the rules of surveys involving human being. Data collection started after a well-done explanation about the procedures by the examiner, followed by the signature of Free Consenting Term containing all information about the study and its purposes.

Sample

Six Parkinson Disease subjects, six subjects after unilateral stroke within anterior circulation and only one episode (measured by the neuroimage exam and a clinical exam) and 6 subjects with pure cerebellum ataxia were selected, both gender, with independent gait and clinical conditions that allowed the proposed tests. To characterize the subjects with Parkinson's disease we used the Hoehn-Yahr Staging Scale and Unified Parkinson's Disease Rating - UPDRS scale which contains 42 items, divided into four parts: mental activity, behavior and mood, activities of daily living (ADLs); exploration and motor complications of drug therapy. The score on each item ranges from 0 to 4, with the maximum value indicates a more severe the disease and the minimum normal. All subjects performed physical therapy at the institution during the collect data process for this study.

Inclusion criteria for the sample were independent walking, only one episode of stroke, Hoehn-Yahr from 1.0 to 1.5 (PD) and clinical conditions that allowed the performance of the proposed task. It was chosen the Hoehn-Yahr 1.0 e 1.5 to keep the sample more homogeneous and to guarantee that the individuals were able to walk independently with safe to perform a dual task. This

category indicates that the individuals were able to walk with no balance disorder and they had unilateral involvement of the limb.

To comprise the Ataxia group, as ataxia is a set of symptoms, we selected only pure cerebellar ataxia caused by cerebellar tumor, cerebellar trauma and cerebellar stroke. The exclusion criteria were: patients who presented gait depending on external sources, presence of cognitive alterations that might affect the comprehension of the proposed tests (punctuation in the Mini Mental State Examination lower than 23 points). The MMSE is composed of several questions typically grouped into seven categories, each designed to evaluate cognitive functions: orientation to time (5 points), orientation to place (5 points), registration of three words (3 points), attention and calculation (5 points), recall of three words (3 points), language (8 points), and visual constructive capacity (1 point). The MMSE score can range from a minimum of 0 to a maximum total of 30 points (Horváth, Tihanyl, & Tihanyl, 2001). The information about sample characterization is shown in Table 1:

Table 1
Sample Characterization

	Stroke subjects (n = 6)	Parkinson subjects (n = 6)	Ataxia subjects (n = 6)
Age (years)	56.2 (6.1)	60.7 (5.8)	53.3 (4.2)
Gender			
Male	4	4	3
Female	2	2	3
Injury Time	8.3 (6.6)	12 (10.3)	5.26 (3.88)
MMSE	24 (1.1)	28 (2.3)	27 (1.0)
UPDRS		27-32	
Hoehn-Yahr		1 – 1.5	

Note. Legend: MMSE: Mini Mental State Examination; UPDRS: Unified Parkinson Disease Rating Scale; Hoehn-Yahr: Hoehn and Yahr Staging Scale.

Materials

The materials utilized were a conventional calculator, an apron with bilateral pockets, a table tennis ball and a Tech Line pedometer.

Study Design

After the subjects selection, gait speed was assessed in an auto selected way, using a 10 meters footbridge without any contestant task for three times consecutive in order to guarantee a value average (Task 1). The assessment method used speed as an isolated measure of functional gait, once it is simple, fast and composed by space and time variables, and this evaluation is prior to analysis of human gait (Roerdink et al., 2006; Titianova, Mateev, Peurala, Sivenius, & Tarkka, 2005).

The measurement of gait speed auto selected by the patient, independent of the kind of surface, has an enormous value, because it represents a cumulative punctuation of trust and skills quality showed by the patient while walking.

Sequentially, gait was assessed in the same space of 10 meters with the contestant activity of cognitive demand for three times consecutive to guarantee a measure of values (task 2), where the patient should memorize a sequence of five numbers during one minute and repeat it verbally while walking.

After this, gait with contestant motor demand was assessed for three times consecutive to guarantee a measure of values (task 3). While doing the 10 meters gait the patient should take a table tennis ball placed in one of the pockets (there were bilateral pockets) and transfer this ball to the other one. Finally, the concurrent associated activity of cognitive and motor demand was assessed for three times consecutive to guarantee a measure of values, where the patient – while walking - should verbally repeat the same number sequence seen before and at the same time type it on the calculator (task 4).

All the tasks were done randomly in a way where the executions were ordered differently for each subject, with no period of rest among them. Data were assessed by the following quantitative measures: speed and number of steps in all the four assessed situations, and these measures were obtained by the digital pedometer and chronometer.

Statistic Analysis

The statistics analyses were based on soft wares: SPSS V11.5, Minitab 14 e Excel XP. For this study, it was used the following non parametric tests: Mann-Whitney, Friedman and Wilcoxon. For complementing the descriptive analysis, it was used the reliability interval for average.

It was established a significance level of .05 (5%). All the reliability intervals constructed during this study were with 95% of statistical confidence.

It is important to emphasize that it was used non parametric tests and techniques, because the conditions as normality and homogeneity of variances could not be achieved in this data group.

Results

The mainly purpose of this study was to investigate the impact of dual task on gait in patients with different injured areas as PD, stroke and ataxia. As a secondary objective, this present study intended to investigate the effect of the type of demand of the secondary task (motor, cognitive and associated) on the gait performance in those patients. So that, the first results will present the intergroup analysis referred to the comparison of group subjects with PD, ataxia and stroke according to the performance during the 4 tasks related to number of steps (Table 2). For this comparison, Kruskal-Wallis test was used.

Table 2
Gait Performance Related to Number of Steps in the Four Tasks for Ataxia, PD and Stroke Groups

Number of Steps		Average	Median	*SD*	CV	Q1	Q3	N	IC	*p*-value
Task 1 Gait	Ataxia	22.17	20.50	8.75	39.5%	16.25	24.00	6	7.00	.002* (a-c)
	PD	16.17	15.00	2.40	14.9%	15.00	15.75	6	1.92	
	Stroke	27.17	23.50	9.20	33.9%	21.50	31.50	6	5.21	
Task 2 Cognitive	Ataxia	26.67	28.50	7.37	27.6%	21.50	32.50	6	5.89	.019* (a-c)
	PD	16.33	16.00	2.42	14.8%	15.25	17.50	6	1.94	
	Stroke	28.00	23.50	9.69	34.6%	20.75	32.50	6	5.48	.001* (b-c)
Task 3 Motor	Ataxia	25.67	28.50	7.28	28.4%	19.75	31.25	6	5.83	.001* (b-c)
	PD	19.33	19.00	2.25	11.6%	17.50	21.25	6	1.80	
	Stroke	33.50	26.50	16.70	49.8%	23.75	39.50	6	9.45	
Task 4 Cognitive-Motor	Ataxia	25.33	28.50	8.21	32.4%	18.25	31.25	6	6.57	.158
	PD	22.67	22.00	5.75	25.4%	18.25	25.00	6	4.60	
	Stroke	35.50	29.50	17.21	48.5%	24.50	39.25	6	9.74	

Note. Legend: PD - Parkinson disease; *SD* - Standard Deviation; CV - coefficient of variability; Q1 e Q3 - quartil 1 e 3; *N* - number of subjects; IC – confidence interval. *Indicates significance.
[a]Ataxia; [b]PD; [c]Stroke.

Analyzing the Table 2 it is possible to notice that there was statistically significant difference among groups for gait tasks, with motor and cognitive demands, for number of steps. In all tasks, stroke group presented the highest value of median and they differ from the other groups on the three tasks already mentioned, though they performed more steps, while the PD group showed less number of steps.

From the analysis of the Figure 1 and considering that lesser the number of steps better the execution of the performed task, it is possible to notice that in ataxia group the gait task presented better performance followed by the other tasks, which presented the same value, and when comparing to the other groups its values were better in the motor and cognitive tasks. The secondary task with motor demand had the best performance in PD group as well as stroke group when compared to the other tasks. The secondary task with cognitive motor demand was the one that originated the worst performance in the subject`s gait.

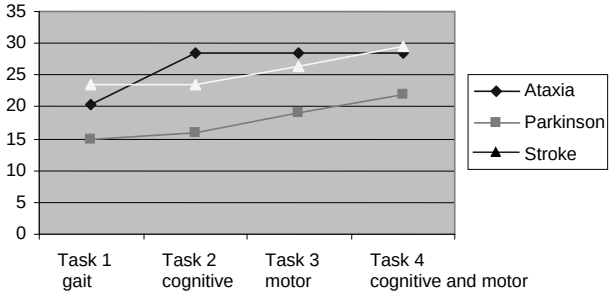

Figure 1. Median values of the number of steps performed by the Ataxia, Parkinson's and stroke groups in the four tasks tested.

Following, Table 3 shows the comparison among the three groups related to the variable average speed of gait during the execution of 4 tasks.

From the analysis of the Figure 2, comparing intergroup values referring to speed average, it was possible to observe that there was statistically significant difference for the groups in the gait tasks and cognitive

Table 3
Performance on Gait Related to Average Speed in the Four Tasks Tested on the Ataxia, PD and Stroke Groups

Average speed		Average	Median	*SD*	CV	Q1	Q3	N	CI	*p*-value
Task 1 Gait	Ataxia	.79	.77	.41	52.3%	.53	.98	6	.33	.002* (b-c)
	PD	1.14	1.13	.20	17.6%	1.00	1.25	6	.16	
	stroke	.61	.64	.26	42.4%	.35	.78	6	.15	
Task 2 Cognitive	Ataxia	.59	.51	.31	53.0%	.35	.86	6	.25	.003* (a-c)
	PD	1.07	1.11	.06	5.3%	1.03	1.11	6	.05	
	stroke	.59	.66	.22	38.1%	.34	.76	6	.13	.001* (b-c)
Task 3 Motor	Ataxia	.63	.57	.35	56.0%	.32	.95	6	.28	.100
	PD	.77	.77	.13	16.8%	.65	.88	6	.10	
	stroke	.50	.55	.23	46.5%	.23	.71	6	.13	
Task 4 Motor – cognitive	Ataxia	.71	.56	.42	58.4%	.40	1.05	6	.33	.193
	PD	.64	.64	.16	24.4%	.57	.66	6	.12	
	stroke	.41	.46	.23	55.6%	.21	.59	6	.13	

Note. Legend: PD - Parkinson disease; CV - coefficient of variability; Q1 e Q3 - quartil 1 e 3; *N* - number of subjects; CI – confidence interval. *Indicates significance.
[a]Ataxia; [b]PD; [c]Stroke.

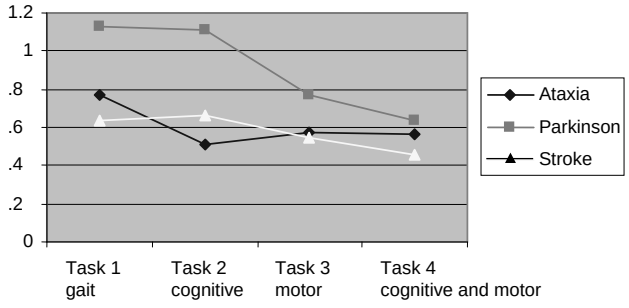

Figure 2. Median values of the average speed performed by the Ataxia, Parkinson's and stroke groups tested in the four Tasks

demand. PD group produced higher speed when compared to the others, except in cognitive motor demand task, where subjects with ataxia were faster.

Though, considering that higher the speed average better the execution of the performed task, it is clear to observe that the group with PD showed better execution in all tasks when compared to the other groups.

Referring to comparative between tasks, stroke group was the group that presented the least values, though, reduced speed, except in the task with cognitive demand, where it presented the same value as the ataxia group.

Discussion

The goal of this study was to investigate the dual task on gait performance in patients with Parkinson`s disease, stroke and ataxia. Based on the results, it was possible to realize, according to the speed of gait, that stroke group showed a reduced performance when comparing to the ataxia group, excepting cognitive demand task, which the subjects with ataxia presented a worse performance.

These findings of damages during performances in dual task after stroke were also found in the study of Roerdink et al. (2006), which verified that stroke patients, when carry out dual task with cognitive demand, show deterioration in the postural control at secondary task (measured by the movement of the gravity center), decreasing local stability. When the results of this study are compared to the present study, it is possible to ratify that for gait performance there is great requirement of postural control and in the presence of instability, caused by the secondary task, the natural tendency for stroke patients was to reduce the media speed of gait, which impacted the performance of primary task. In a similar study Torriani-Pasin, Lin, Arjona, Silva, and Lima (2010) the post stroke hemiparetic patients showed statistically significant differences with deterioration of performance related to a control group, independently in a single or dual task. Therewith, it is possible to confirm

that beyond the age, brain injury probably worsen much more the dual task performance, as predicted by Yea-Ru et al. (2006).

PD group demonstrated better performance in dual task when compared to the other groups, situation that surprises as shown by injured topographic in PD and the expected damages during the performance of automatic movements. On the other hand, whether the automatic movements are impaired they allocate attention (using the available cortical resources) to perform the task. And, for mild PD patients with unilateral impairment this allocation seems to work to keep the motor performance of the primary task better.

These findings may give attention to the slight dysfunction of PD patients in the constitution of these sample (as shown by the time of the injuries), but also allows affirming that stroke and ataxia patients were more impacted by dual task, especially with cognitive demand in the secondary task. These damages observed in patients with stroke and ataxia may be explained due to the fact that injured topographic area after stroke and ataxia damages cognitive functions, even considering the punctuation at MMSE as an exclusion criterion. For stroke group the injured topographic area was in the anterior circulation and, therefore, it may have damaged the cognitive functions, as memory, as in the ataxia, considering the cerebellum dysfunction, which is a region known by its motor cognitive functions and the storage of the motor memory (Bugalho, Correa, & Viana-Baptista, 2006; Gordon, 2007).

In a study of O'Shea et al. (2002), it was observed that PD patients presented less number of steps and slower speed while doing dual task, when compared to the control group. But, when compared to the ataxic and stroke patients the PD group showed a better performance. It may indicate that the secondary tasks with motor and cognitive demand can affect in a different way the performance of ataxia, stroke and PD patients, requiring, thus, different types of interventions for these three neurological groups, due to the local of the lesion.

Relating to number of steps, PD group showed better performance when compared to the others. And, the same way for speed gait, the post stroke group showed higher number of steps to go through the same distance.

In the present study, the post stroke hemiparetic patients did not showed total availability to do the second task concurrent to the gait, and the primary task, in this case, the gait, even being an extremely practiced skill before the stroke and inherent to human being, it stills requires much attention from the patients and does not collaborate to the availability of necessary attention to combine a second task. The post stroke patients might had been the most affected group while doing the dual task, because due to hemiparesis, they are asymmetric and the gait pattern chosen in general, gives this asymmetry to the steps, related to the number of steps and also the length of them. Besides, when performing a dual task they need to allocate attention to the secondary task and they do not have gait as an automatic skill. So that, the deficits found on gait speed might be explained by the necessity to use cortical resources (not totally available) to perform the task.

The secondary task with motor demand had a less important impact even in the PD group as in stroke group comparing to the other tasks. The secondary task with motor cognitive demand was the one that had the worst impact on gait performance. According to the Cockburn, Haggard, Cock, and Fordham (2003) a secondary task with motor cognitive demand requires more cerebral connections and constant improving due to the complexity of the task, and the negative effects are more evident observed in the concurrent task. From the findings of this present study, it is possible to affirm that the association of motor cognitive demand as a secondary task reflects on the performance of the primary task in PD, stroke and also patients with ataxia; however, even with great complexity, it is not the task that damages the performance of these groups of patients.

While analyzing ataxia subjects' data, related to the type of the purposed tasks as secondary to the gait execution, it is possible to confirm that, according to the number of steps, the ataxia subjects were disturbed in the same form during the performance of concurrent task. Though, connect the memory activity to the gait impacts with the same magnitude when connecting hands coordination task to memory tasks associated to manual activities. These findings emphasize the great importance of the cerebellum in cognitive functions and not only as a receptor and comparator of afferent stimulus from different areas of the nervous system. In a study of Torriani-Pasin, Arjona, Leitão, Lima, and Cyrillo (2010), when patients with ataxia were compared to the control group in the execution of a motor cognitive task, it was detected the associated concurrent task has damaged the visual control during the gait. The authors discussed that the balance of these patients was challenged and this fact can explain the worst performance in patients with pure cerebellar ataxia when compared to the control group.

Synthetically, gait performance in dual task for post stroke and ataxia patients seems to be more impaired than the performance of patients with PD. We should emphasize that the subjects with PD of this sample are at an early stage of the disease, with unilateral impairment and without balance deficit, so the findings can not be extended to patients in advanced stages of PD. These findings can have implications during the elaboration of interventions programs to these patients so far as the daily activities are composed by dual tasks and patients must be trained to deal with motor cognitive interference situations caused by them.

As limitations of the present study it can be established that the sample is not comprised by a large number of patients and, as we compared three different conditions, the total of subjects in each group is reduced. The sample size was not calculated because it is a pilot study and the authors intend to continue the investigation on the theme.

The dependent variables were based on the clinical point of view and we suggest to the next studies that the measurements regarding the gait while performing a dual task were more accurate, using kinematic analysis.

Conclusion

In this study the impact of dual task was minor in PD patients in initial phase when compared to stroke and ataxia group, thus PD group presented better performance in speed of gait as well as in the number of steps.

References

Beauchet, O., & Berrut, G. (2006). Gait and dual task: Definition, interest and perspectives in the elderly. *Psychologie & NeuroPsychiatrie du Vieillissement, 3*, 215-225.

Bond, J. M., & Morris, M. E. (2000). Goal-directed secondary motor tasks: Their effects on gait in subjects with Parkinson's disease. *Archives of Physical Medicine and Rehabilitation, 81*(1), 110-116.

Bugalho, P., Correa, B., & Viana-Baptista, M. (2006). Papel do cerebelo nas funções cognitivas e comportamentais – Bases científicas e modelos de estudo. *Acta Médica Portuguesa, 19*, 257-268.

Caldas, A. C. (2000). *A herança de Franz Joseph Gall: O cérebro ao serviço do comportamento humano*. Lisboa, Portugal: McGraw-Hill.

Cockburn, J. M., Haggard, P., Cock, J., & Fordham, C. (2003). Changing patterns of cognitive-motor interference (CMI) over time during recovery from stroke. *Clinical Rehabilitation, 17*, 167-173.

Gordon, N. (2007). The cerebellum and cognition. *European Journal of Paediatric Neurology, 11*(4), 232-234.

Haggard, P., Cockbum, J., Cock, J., Fordham, C., & Wade, D. (2000). Interference between gait and cognitive task in a rehabilitating neurological population. *Journal of Neurology, Neurosurgery, and Psychiatry*, 479-486.

Horváth, M., Tihanyl, T., & Tihanyl, J. (2001). Kinematic and Kinetic analyses of gait patterns in hemiplegic patients. *Physical Education and Sport, 1*(8), 25-35.

Kandel, E. R., Schwartz, J. H., & Jessel, T. M. (1997). *Fundamentos da neurociência e do comportamento*. Rio de Janeiro, RJ: Prentice Hall do Brasil.

O'Shea, S., Morris, M. E., & Iansek, R. (2002). Dual task interference during gait in people witch Parkinson disease: Effects of motor versus cognitive secundary tasks. *Physical Therapy, 82*(9), 888-897.

Roerdink, M., De Haart, M., Daffershofer, A., Donker, S. F., Geurts, A. C., & Beek, P. J. (2006). Dynamical structure of center-of-pressure trajectories in patients recovering from stroke. *Experimental Brain Research, 174*, 256-269.

Teixeira, N. B., & Alouche, S. R. (2007). O desempenho da dupla tarefa na doença de Parkinson. *Revista Brasileira* de *Fisioterapia, 11*(2), 127-132.

Titianova, E. B., Mateev, O. S., Peurala, S. H., Sivenius, J., & Tarkka, I. M. (2005). Footprint peak time and functional ambulation profile reflect the potential for hemiparetic gait recovery. *Brain Injury, 19*(8), 623-631.

Torriani-Pasin, C., Arjona, M., Leitão, R. G., Lima, R. Z., & Cyrillo, F. N. (2010). Efeitos da dupla tarefa na marcha de pacientes atáxicos. *Science in Health, 1*(2), 101-110.

Torriani-Pasin, C., Lin, K., Arjona, M., Silva, P. Y., & Lima, R. Z. (2010). Efeitos da dupla tarefa na marcha de pacientes hemiparéticos. *Science in Health, 1*(3), 128-35.

Wu, T., & Hallet, M. (2008). Neural correlates of dual task performance in patients with Parkinson's Disease. *Journal of Neurology, Neurosurgery, and Psychiatry, 79*, 760-766.

Yea-Ru, Y., Yu-Chung, C., Chun-Shou, L., Shih-Jung, C., & Ray-Yau, W. (2006). Dual-task-related gait changes in individuals with stroke. *Gait and Posture*, 185-190.

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