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ARTICLE

Walking execution is not affected by divided attention in patients with multiple sclerosis with no disability, but there is a motor planning impairment

A execução da marcha não é afetada pela atenção dividida em pacientes com esclerose múltipla sem incapacidade, mas existe um comprometimento do planejamento motor

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ABSTRACT

Purpose: We analysed the cognitive influence on walking in multiple sclerosis (MS) patients, in the absence of clinical disability. **Method:** A case-control study was conducted with 12 MS patients with no disability and 12 matched healthy controls. Subjects were referred for completion a timed walk test of 10 m and a 3D-kinematic analysis. Participants were instructed to walk at a comfortable speed in a dual-task (arithmetic task) condition, and motor planning was measured by mental chronometry. **Results:** Scores of walking speed and cadence showed no statistically significant differences between the groups in the three conditions. The dual-task condition showed an increase in the double support duration in both groups. Motor imagery analysis showed statistically significant differences between real and imagined walking in patients. **Conclusion:** MS patients with no disability did not show any influence of divided attention on walking execution. However, motor planning was overestimated as compared with real walking.

Key words: mild cognitive impairment, multiple sclerosis, walking.

RESUMO

O objetivo do estudo foi analisar a influência cognitiva na caminhada de pacientes com esclerose múltipla (EM) sem incapacidade clínica. Foi conduzido um estudo caso-controle com 12 pacientes com EM sem incapacidade com 12 pessoas saudáveis como controles pareados. Os sujeitos fizeram um teste de caminhada de 10 metros , acompanhado de análise cinemática 3D, e foram orientados a caminhar em velocidade confortável, realizando dupla-tarefa (tarefa aritmética), e o planejamento motor foi medido pela cronometria mental. Os valores de velocidade da caminhada e da cadência não evidenciaram diferenças estatisticamente significativas entre os grupos nas três condições. A condição de dupla-tarefa demonstrou um aumento na duração do duplo apoio em ambos os grupos. A imagética motora evidenciou diferenças estatisticamente significativas entre a caminhada real e a imaginada nos pacientes com EM. Pacientes com EM sem incapacidade não apresentaram influência da atenção dividida na execução da caminhada. Entretanto, o planejamento motor esteve superestimado.

Palavras-Chave: comprometimento cognitivo leve, esclerose múltipla, caminhada.

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Difficulty experienced while walking is the most visible sign of the functional impairments caused by multiple sclerosis (MS)[1]. Only 21% of the MS patients estimate their walking ability correctly[2]. The need to concentrate on walking, caused by MS, was the most common problem found in a study involving 703 patients[1]. Walking is a complex sensorimotor task, requiring a dynamic interaction between the spinal locomotor pattern generators and the hierarchically organised supraspinal locomotion centres in the brainstem, cerebellum and forebrain[3]. Walking has traditionally been considered as an automatic or reflex-controlled task; however, recent studies have suggested that there are significant attention requirements for postural and balance control[4]. Epidemiological, cognitive and neuroimaging studies suggest that walking is influenced by higher order and cortical control mechanisms[5].

Cognitive deficits can lead to gait instability and an increase in gait variability. Cognitive impairment in MS ranges from 40% to 65%, and cognitive dysfunction has been consistently demonstrated even in patients with clinically isolated syndromes, with early-stage disease and with low disability levels[6]. MS pathophysiology involves spinal and supraspinal white matter lesions. Both cross-sectional and longitudinal studies have found that white matter changes are associated with gait disturbance and falls[7].

MS patients have both motor and cognitive impairments, making them vulnerable to dual-tasking. Dual-tasks require an individual to have the ability to simultaneously perform two tasks. When two tasks are simultaneously performed, more than the total capacity of the individual is required and the performance of either or both tasks can deteriorate[4]. Studies that have analysed attention and gait have used the dual-task paradigm, using gait as a primary task and a simultaneous secondary cognitive task. Gait analysis conducted while dual-tasking was usually based on visual observation in most prior studies, reporting various dual-task-related gait changes such as increase in walking time, number of steps and mediolateral deviation[8].

Cognitive aspects of the neural control of action and motor planning in the absence of sensorimotor feedback has been widely studied by motor imagery (MI)[9]. MI can be defined as a dynamic state during which an individual mentally simulates a given action without any motor output[10]. Brain activation during locomotion-imagined movement has the same pattern but with a lower amplitude as compared with active movement[11]. Clinically, mental chronometry can be reliably used for the screening of patients capable of MI or for measuring the temporal congruency between real and imagined movements[12].

Early stages of MS show compensatory cortical activations, mainly located in regions involved in executive processing[13]. The aim of this study was to analyse the cognitive influence on walking in patients with MS, in the absence of clinical disability. There is a lack of studies assessing the effect of dual-task on MS patients. To the best of our knowledge, in previously published literature, there is no description on the influence of MI or motor planning on walking in MS patients.

METHODS

Subjects

A case-control study was conducted with two groups of subjects (MS patients and control patients). Data were collected at the Physical Therapy clinic of Gaffrée and the Guinle University Hospital (GGUH), Rio de Janeiro, Brazil. Twelve subjects diagnosed with MS (average age: 30.6 years, average height: 168 cm, average weight: 67.17 kg, gender: 9 females and 3 males and average International Physical Activity Questionnaire score: 3221.75) and 12 healthy control subjects (average age: 33.2 years, average height: 169 cm, average weight: 68.17 kg, gender: 9 females and 3 males and average International Physical Activity Questionnaire score: 3874.62) participated in this study. No statistically significant differences were found between the study groups. The patients were recruited from the outpatient clinic of GGUH, and a control group of healthy subjects was recruited from the staff and student community of the physical therapy department. The inclusion criteria consisted of a diagnosis of MS according to the criteria established by McDonald et al.[14] and no disability on the Expanded Disability Status Scale (EDSS≤1.5). The exclusion criteria included patients with other forms of idiopathic demyelinating disease, patients currently undergoing an MS attack and patients with another associated neurological disease. The control subjects were healthy adults without a clinical diagnosis of MS and no reports of neurological impairments. Subjects from the MS group were matched with subjects from the control group, based primarily on gender and age, followed by an agreement between the subject pairs in terms of height, weight and physical activity level. The study was approved by the Human Research Ethics Committees of GGUH, and all subjects provided informed consent prior to their participation in the study.

Procedures

After providing informed consent, the subjects underwent a clinical neurological evaluation to determine their disability level on the EDSS. The subjects were then referred for completion of the gait clinical trials and 3D-kinematic analysis. Gait was assessed by two tests: 10-m timed walk-test (10m-TWT) and 3D-kinematic analysis. The use of video analysis software is an efficient approach to improve the reliability of visual video assessments[15]. Initially, participants were instructed to walk at a comfortable speed along a 14-m walkway, then, the subjects were similarly instructed to perform 10m-TWT while executing an arithmetic task; motor planning was measured by mental chronometry.

Instruments

Disability

A standardised, bedside neurological examination was performed by a neurologist. The scores obtained in this examination allowed neurological impairment and disability to be established using the EDSS. Clinicians determined a patient's EDSS level by first assigning a separate grade for the eight functional systems, including pyramidal, cerebellar, bowel and bladder, cerebral, brain stem, sensory, visual and other functions. A composite of grades was then used to determine an individual's EDSS score, ranging from 0 (normal neurologic exam) to 10.0 (death due to MS)[16]. The EDSS is the most widely used scale for MS disability and is a commonly used rating system for evaluating the degree of neurological impairment in MS based on neurological findings.

Gait clinical trial

Participants were instructed to walk barefoot at a self-selected, comfortable speed along a 14-m walkway. A 'dynamic start' was used, where the subject may accelerate 2 m before entering the timed 10 m distance and decelerate 2 m afterwards. As long as the subjects were capable of ambulating the required 14 m, they were allowed to participate in the test. Timing was marked when the lead foot crossed the starting line and was stopped when the lead foot crossed the finish line. Speed was only calculated for the 10 m distance between the starting and the finish line, to avoid measuring the acceleration and deceleration phases of gait. The second walking trial was recorded to minimise the learning effect. The walking time and the number of steps were registered. The gait speed, cadence, step and stride length were then estimated. The 10m-TWT is a valid and reliable measure for patients with neurological impairment[17].

3D-kinematic analysis

Video analyses were simultaneously performed in the same environment. A three-dimensional analysis was performed with four video camera recordings (Kodak Zi10 sampled at 60 frames per second). Data were collected across the central 4 m of the walkway to exclude the acceleration and deceleration phases of each trial. To evaluate the hip, knee and ankle kinematics during gait, 15 adhesive markers were attached to the subjects to define the thigh, shank and foot segments, according to the Helen Hayes protocol previously described for gait analysis[18]. The same examiner placed the markers. The Human software (HMA Technology) was used for video analysis. For three-dimensional analysis, the software accepts two-dimensional source digitised data and uses a direct linear transformation to produce the 3D coordinate file. A gait cycle was digitised and synchronised for each subject. The 3D-kinematic analysis was used to objectively measure the cadence (steps per minute), swing phase (% gait cycle), stance phase (% gait cycle), double support duration (% gait cycle) and step width (cm). The kinematic method is the most accurate method to measure the temporal-spatial gait characteristics.

Dual-task

Subjects were similarly instructed to perform the 10m-TWT while executing an arithmetic task, namely, counting aloud backwards from 100, subtracting by 3, to manipulate the attention demands of subjects during a motor task. One investigator walked beside the patients adjacent to the walkway to provide support if a loss of balance occurred. Gait speed and cadence were measured by 10m-TWT.

Motor planning

Motor planning was measured by mental chronometry. This strategy is based on the observation that the duration of mentally simulated and executed motor tasks are comparable. Thus, knowing the time length of the physical act, the investigator asked the patient to signal the beginning and termination of the imagined movement. A comparable time period of the imagery and physical performance of the task is considered to be an evidence of the engagement in MI practice of the required task. Subjects were instructed to imagine themselves (first-person perspective) walking along the walkway, then, kinaesthetic MI was used. Bakker et al.[9] showed that kinaesthetic MI has higher correspondence with gait execution than visual MI. The motor planning results were obtained from the walking imagination time along the 10 m distance. The average walking speed in the physical act and the imagined movement (MI) were compared to analyse the motor planning congruence.

Data analysis

Normal probability plots were inspected for each variable. The data distribution of each variable was verified through the Shapiro–Wilk test. Comparison between the groups was performed using the paired and non-paired Student's *t*-test or the Mann–Whitney U test. The χ^2 test was used to analyse categorical variables. Significance level was established at 5% ($p<0.05$). All data were analysed using the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, Illinois, US) version 17.0 software.

RESULTS

Twenty-four subjects participated in the study: 12 MS patients with no disability and 12 matched healthy controls.

Most of the participants were young adults with female predominance and normal body fat. There were no differences in the falls history and education level between the groups. Patient demographic data are shown in Table 1.

The scores of walking speed and cadence showed no statistically significant differences between the groups in comfortable walking, dual-task condition and MI. The dual-task condition showed an increase in double support duration in both groups. However, step width did not show any significant differences between comfortable walking and the dual-task condition in both groups. The temporal-spatial walking values are described in Table 2. The comparison of double support duration in MS patients and healthy controls in normal walking and dual-task conditions is presented in Figure 1.

MI analysis showed statistically significant differences between real and imagined walking in MS patients (MI=1.90 m/s, SD±0.93 vs. normal walking=1.27 m/s, SD±0.24; p=0.02), while healthy controls showed a tendency to higher the walking speed in imagined walking, but this result was not statistically significant (MI=1.55 m/s, SD±0.52 vs. normal walking=1.21 m/s, SD±0.11; p=0.05). MS patients overestimated walking speed by 33%, while matched healthy controls overestimated walking speed by 22%. Figure 2 shows the comparison in walking speed in MS patients and healthy controls in normal walking and MI conditions.

DISCUSSION

MS patients with no clinical disability did not show any influence of divided attention on gait execution; however, motor planning was overestimated compared to real walking.

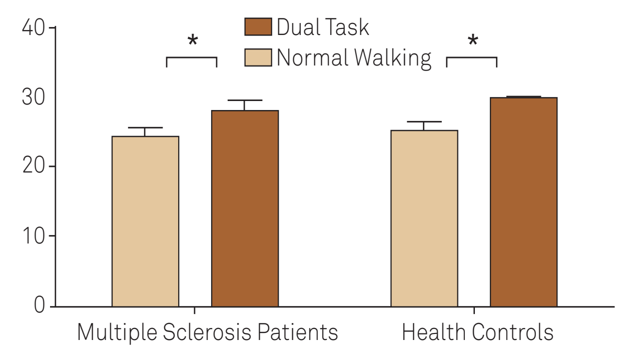

Fig 1. Comparison of double support duration in multiple sclerosis patients and healthy controls in normal walking and dual-task conditions.

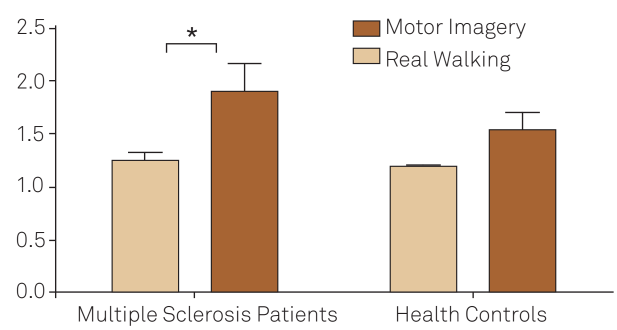

Fig 2. Comparison of walking speed in multiple sclerosis patients and healthy controls in normal walking and motor imagery conditions.

Table 1. Demographic data of the multiple sclerosis patients and healthy control group.

	MS patients (n=12) (mean±SD)	Healthy controls (n=12) (mean±SD)	p-value*
Age (years)	30.56±5.01	33.17±7.28	0.33
Gender (female/male)	9:3	9:3	1.00
Weight (kg)	67.17±13.07	68.17±17.15	0.87
Height (metres)	1.68±0.10	1.69±0.09	
BMI	23.16±3.16	23.00±3.67	0.90
Number of falls (total)	2	1	0.65
Years of education	18.00±2.15	19.5±1.57	0.09

BMI: body mass index; MS: multiple sclerosis; SD: standard deviation; *Significance level <0.05.

Table 2. Comparison of temporal-spatial characteristics in multiple sclerosis patients and healthy control patients in comfortable walking and dual-task conditions.

	MS patients (n=12)			Healthy controls (n=12)		
	Comfortable walking (mean±SD)	Dual-task (mean±SD)	p-value	Comfortable walking (mean±SD)	Dual-task (mean±SD)	p-value
Walking speed (m/s)	1.27±0.24	1.19±0.23	NS	1.21±0.10	1.18±0.13	NS
Cadence (steps/min)	117.21±12.93	118.12±19.84	NS	110.79±5.38	110.00±3.11	NS
Double support duration (%)	24.38±3.85	27.96±5.21	<0.01*	25.17±4.12	29.75±1.82	<0.01*
Step width (cm)	13.7±4.43	12.32±4.21	NS	11.81±3.14	13.04 (3.64	NS

MS: multiple sclerosis; SD: standard deviation; *Significance level <0.05; NS: not significant.

A matched healthy control group did not show overestimation of motor planning in the same task. MI-based exercises, as a therapy tool, have been used for Parkinson's disease and post-stroke patients, with good results. However, for MS patients, it is important to consider their ability to generate correct motor images. Cognitive impairments are highly prevalent in MS patients, even in early stages, and in patients with mild disability measured by the EDSS[6].

The dual-task condition did not show any differences in walking speed, cadence and step width. However, double support duration significantly increased. A previous study showed that cadence does not differ with dual-task condition's clinically isolated syndromes, suggestive of MS[19]. The increase in double support duration was a compensatory strategy to maintain walking stability. Hamilton et al.[20] showed greater decrements in performance under dual-task conditions in cognitive task performance, walking speed and swing-time variability in MS patients. Kalron et al.[19] also showed that combined walking and cognitive tasks were expressed in prolonged double support duration, as shown by the present results. They also described a reduction in gait speed in the early stages of the disease. Our results showed an increase of 13% in double support duration in dual-task conditions, while Kalron et al.[19] showed an increase of 8% in double support duration. Despite the similarity of results, the differences found in both studies may be related to the methods used as Kalron et al.[19] used the Word List Generation Test as the executive function, while we used an arithmetic task. Stoquart-Elsankari et al.[21] showed that the action slowing of an MS patient was mainly related to the attention deficit, even in patients without motor deficit on clinical examinations, where divided attention and decisional processes were preserved. MS patients showed an interference of cognitive task on motor execution although the severity of clinical disability with more impairment, as compared with healthy subjects, still needs to be clarified.

The double support duration was increased in patients and matched healthy controls during the dual-task condition. Slower walking speed[5,22] and an increase in stride-time variability are common findings, even in healthy adults performing dual-tasks[22]. Walking speed is the most common finding described in studies with dual-task condition and it is usually slower in many populations. The results of the present study reflect the increase of walking stability under cognitive demands. A functional magnetic resonance imaging study, with different types of dual-tasks, revealed that cortical areas along the inferior frontal sulcus, middle frontal gyrus and intraparietal sulcus are involved in dual-task performance, which highlights the role of cognitive function and the frontal lobe on mobility[23]. The question that should be asked is at which stage of the MS disease process do dual-task conditions affect gait performance; specifically, which gait parameters are affected and to what extent.

MS patients with no disability showed a reduction in motor planning accuracy compared with matched healthy controls. A recent study[24], which was the first research that investigated MI in MS patients, focused on upper limb movement capacity and described significant differences in temporal organisation. Heremans et al.[24] used mental chronometry during the Box and Block Test in moderate disability (average EDSS=6.5) in MS patients. The present study showed that MS patients overestimated the imagined movement by 33%, while Heremans et al.[24] showed an increase of 14% in the upper limb most affected side. The temporal invariance between executed and imagined movements, which was well documented in young adults, suggests that similar motor representations are shared between covert and overt stages of actions[25]. Young adults had their MI ability preserved irrespective of the width of the path, while the elderly group significantly overestimated the duration of imagined movements with respect to the executed movements[26]. MI accuracy was significantly deteriorated in elderly adults; this could be attributed to functional changes in the brain that occur with ageing, influencing cognitive and motor abilities[25]. The temporal congruence of real and imagined movements in post-stroke patients remains similar to that of age-matched controls[27].

Neuroimaging studies have been described to have remarkable similarities between the real and imagined locomotion network. The major activated areas were the motor/premotor and multisensory cortices, parahippocampal gyri and midline cerebellum. There were deactivations in multisensory vestibular cortical areas in both conditions[28]. In MS patients, it has been shown that an ipsilateral sensorimotor cortex deactivation with a simple motor task[29] and an existence of compensatory cortical activations at the earliest stage of MS were mainly located in regions involved in executive processing[13,30].

The sample size was a potential limitation of this study. Therefore, the possibility of making generalisations from our findings may still be fairly limited. The second possible limitation is that we did not find any gait research in MS patients with no disability (EDSS≤1.5) that analyses the influence of motor planning with which to compare our data. Despite these limitations, the originality of the research theme and intriguing results provide an impetus for future research. Studies with larger sample sizes that include participants with greater disability from the present study and different levels of cognitive impairments should be undertaken to confirm the present results.

In conclusion, MS patients with no disability did not show any influence of divided attention on walking execution. However, MI time was overestimated compared to real walking, revealing a motor planning impairment. A matched healthy control group did not show overestimation of motor planning to the same task.

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