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Texting while walking differently alters gait patterns in people with multiple sclerosis and healthy individuals

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A R T I C L E I N F O

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A B S T R A C T

Background: In recent times, increasing safety concerns have been associated with the use of mobile phones by pedestrians. In particular, texting has been shown to significantly alter gait patterns. However, no specific investigations have been performed on people with Multiple Sclerosis (pwMS), who are already characterized by gait dysfunctions caused by the disease.
Objective: To assess the existence of possible alterations in spatio-temporal parameters of gait in pwMS when simultaneously texting on a smartphone and walking.
Methods: Fifty-four pwMS (mean age 40.5 ± 10.5) and 40 age-matched unaffected individuals were tested in two conditions: walking, and walking while texting on a smartphone. Spatio-temporal parameters of gait were assessed using a wearable accelerometer located on the lower back.
Results: Texting induces reduction of gait speed, stride length and cadence in both groups, but such changes were smaller in magnitude in pwMS. An increase of stance and double support and reduction of swing phase were observed in pwMS only.
Conclusions: Texting alters gait patterns of pwMS differently from unaffected individuals, probably due to a different prioritization of the task, which appears to take into account the motor and sensory impairments associated with the disease by favoring the motor task.

1. Introduction

The use of modern communication technologies is widespread among people with Multiple Sclerosis (pwMS). According to a recent survey, 90% of them own a mobile phone they use regularly not only to communicate, but also to retrieve health-related information online and interact with MS health care services (Haase et al., 2013). The use of such devices involves a significant cognitive demand on the working memory but, at the same time, requires physical resources associated with the manipulation of the phone itself (Banducci et al., 2016; Lim et al., 2017). The combination of such factors may represent a source of distraction and a potential hazard when the user is simultaneously engaged in other activities such as driving, operating machines or simply crossing a street.

In particular, interference between texting and walking has been extensively investigated in the last few years owing to the increasing number of pedestrian injuries related to mobile phone use, which increased by about six times between 2005 and 2012 in the USA (Nasar and Troyer, 2013; Saltos et al., 2015). Statistics show that the incidence of texting-related injuries in the USA increased continuously (from 100 to 1500 in the period 2009–2012) (Saltos et al., 2015) probably also owing to the availability of free messaging services (i.e. WhatsApp, Facebook Messenger etc.) which have become widespread in recent years.

Several studies performed in the last few years on healthy young adults report that texting while walking results in significant reductions of gait speed and stride length and in increases of double support phase duration in both laboratory and "ecological" environments (Lamberg and Muratori, 2012; Kim et al., 2014; Schabrun et al., 2014; Agostini et al., 2015; Licence et al., 2015; Lim et al., 2015; Plummer et al., 2015). However, to the authors' knowledge, no investigations have been carried out on individuals with diseases able to significantly affect gait such as MS.

In pwMS, the combination of symptoms such as fatigue, muscular weakness, spasticity and ataxia with balance deficits originates gait dysfunctions typically expressed in the form of reduced gait speed,

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decreased step length and cadence, and alteration of the physiological stance/swing phase duration (Cameron and Wagner, 2011). Such alterations become even more evident when a concurrent cognitive task is performed and this paradigm is widely used in laboratory to reproduce daily life situations in which walking is performed in complex/challenging environmental conditions (Leone et al., 2015). However, since few studies have specifically investigated cognitive-motor interference in both pwMS and healthy controls, it is still not perfectly clear if (and how) the presence of the disease exacerbates the deterioration of gait patterns, that is, if the dual-task cost for spatio-temporal parameters of gait is significantly higher in pwMS. In this context, the use of texting as a cognitive task during walking represents an approach very close to real life situations.

Based on such considerations, the main purpose of the present study is to assess to what extent gait patterns are modified when pwMS and unaffected individuals walk while simultaneously texting on a smartphone in a controlled indoor environment. Our hypothesis is that in pwMS the presence of the disease induces peculiar changes in spatio-temporal parameters of gait, which are different from those of healthy individuals owing to different modalities of task prioritization.

2. Methods

2.1. Participants

A convenience sample of 54 pwMS (13M, 41F, age 40.5 ± 10.5) followed at the Regional Multiple Sclerosis Center of Sardinia (Cagliari, Italy) were enrolled in the study on a voluntary basis. All of them had received a diagnosis of MS by a neurologist expert in MS (EC, GC) according to the 2010 revised criteria (Polman et al., 2005, 2011) and their disability was quantified using the Expanded Disability Status Scale (EDSS) score (Kurtzke, 1983).

Inclusion criteria were the ability to ambulate with no assisting device (i.e. cane, crutches or walking frames) for at least 100 m, absence of any other condition potentially able to severely affect gait (assessed by the neurologist after careful examination of the participant's anamnesis), normal/corrected to normal visual acuity and being a regular user of a mobile phone for several times a day (according to the questionnaire proposed by Haase et al., 2013 for pwMS) equipped with a touch screen and standard QWERTY keyboard.

A control group of 40 age-matched healthy individuals (HC) was recruited among medical staff and pwMS relatives and caregivers. The study was approved by the local ethics committee and conducted according to the principles expressed in the World Medical Association Declaration of Helsinki, and all participants signed an informed consent agreeing to participate. Participants' main features appear in Table 1.

2.2. Experimental procedure

Participants were tested under two conditions: they were first requested to walk along a straight path in a 20 m hallway at self-selected speed, then perform a second trial during which they had to digit on a smartphone (Samsung Note 3) a number of words displayed on the screen after random selection by a dedicated application (Fast Type ver. 1.55, http://frozened.me/) previously employed in similar studies (Lim et al., 2015). Before final acquisition, participants were allowed to familiarize with both the smartphone and the application to limit the influence of possible confounding effects originated by the use of a different device with respect to those they daily employ. The texting performance was assessed by calculating the ratio between the number of words correctly typed by the number of those displayed by the application during the trial time.

2.3. Quantitative measurement of gait parameters

Spatio-temporal parameters of gait were acquired using a wireless inertial sensor (G-Sensor®, BTS Bioengineering S.p.A., Italy), previously employed to characterize gait and functional mobility in pwMS (Pau et al., 2016, 2017). This miniaturized wearable unit includes a triaxial accelerometer, a gyroscope, and a magnetometer, and allows assessment of spatio-temporal parameters of gait through processing of trunk accelerations.

The sensor, attached at the lower lumbar level (centered on the L4–L5 intervertebral disc) with a semi-elastic belt, during walking acquires acceleration values along three orthogonal axes (anteroposterior, mediolateral, and superoinferior) and transmits them via Bluetooth to a PC. At the end of the trial, raw data are processed with dedicated software (BTS Bioengineering G-Studio®) to derive the following gait parameters:

- Stride length: distance between two consecutive heel contacts of the same foot (m);
- Gait speed: mean instantaneous speed within the gait cycle (m s^{-1});
- Cadence: number of steps per minute (steps min^{-1});
- Stance and swing duration: expressed as a percentage of the gait cycle, representing the proportion of a gait cycle involving foot support (from heel strike to toe with the same foot) and swing of the lower limb;
- Double support duration: the duration of phase support on both feet, expressed as a percentage of the gait cycle.

Parameters are calculated by automatically discarding the first and last stride, to consider only stationary conditions (i.e. constant speed).

2.4. Statistical analysis

The possible alterations introduced in gait patterns by the concurrent cognitive task (i.e. texting) were explored using two-way analysis of variance for repeated measures (RM-ANOVA) considering as independent variables the participant's group (MS or HC) and the task (walking or walking + texting) and as dependent variables the 6 previously listed spatio-temporal parameters. The level of significance was set at $p = 0.05$ and effect sizes were assessed using the eta-squared coefficient (η^2). In the case of a significant effect of group or task, a post hoc Holm-Sidak test for pairwise comparison was carried out to assess intragroup and intergroup differences. A t-test was also performed to

Table 1
Anthropometric and clinical features of the participants. Values are expressed as mean ± SD.

	MS		HC		
	Mean values	**Range**	**Mean Values**	**Range**	*p-value*
Participants #	54 (13M, 41F)	–	40 (11M, 29F)	–	–
Age (years)	39.8 ± 10.7	25–62	41.3 ± 10.4	26–64	0.549
Height (cm)	164.1 ± 9.7	145–192	165.1 ± 8.0	150–183	0.594
Body Mass (kg)	60.1 ± 11.5	43–91	62.6 ± 11.4	43–90	0.295
EDSS Score	2.4 ± 1.2	1–5.5	–	–	–

MS: Multiple Sclerosis HC: Healthy Controls.