Journal of the Neurological Sciences xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Journal of the Neurological Sciences

journal homepage: www.elsevier.com/locate/jns

Effect of spasticity on kinematics of gait and muscular activation in people with Multiple Sclerosis

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ARTICLE INFO

Article history:
Received 30 June 2015
Received in revised form 25 August 2015
Accepted 14 September 2015
Available online xxxx

Keywords:
Spasticity
Multiple Sclerosis (MS)
Gait
Gait Profile Score (GPS)
Motion analysis
Kinematics
Expanded Disability Status Scale (EDSS)
Electromyography (EMG)

ABSTRACT

Purpose: This study proposes to characterize the gait patterns of individuals with Multiple Sclerosis (MS) affected by spasticity using quantitative gait analysis.
Method: Cross-sectional study on 38 individuals with MS, 19 affected by lower limb spasticity and 19 not affected, the latter forming the control group. Both groups were evaluated while walking using three-dimensional gait analysis. Spatio-temporal parameters of gait, kinematic data expressed by means of Gait Profile Score (GPS) and Range of Motion (ROM), as well as muscular activation, were evaluated.
Results: The results show that spasticity originates a peculiar gait pattern characterized by reduced speed, cadence, stride length, swing phase and increased double support time, but they also reveal specific alterations in kinematics and muscular activation. In particular, significantly higher values of GPS, reduced hip and knee flexion-extension ROM and abnormal activation of the rectus femoris were observed in individuals with spasticity.
Conclusions: In people with MS presenting spastic gait, the availability of quantitative data appears crucial in verifying the effectiveness of pharmacologic and rehabilitative treatments, also considering that spasticity scales may not be satisfactory in relating the assessed spasticity with both perception of the patients and the actual body functionalities.

1. Introduction

Among the wide spectrum of signs and symptoms associated with Multiple Sclerosis (MS), spasticity (i.e. a velocity-dependent increase in muscle resistance in response to a passive stretch [1]) represents one of the most commonly observed. In fact, it has been estimated that approximately 30–50% of individuals with MS exhibit spasticity following a physical examination or self-report [2–3] even though up to 90% of them result affected by it at a certain point of their disease history [4].

The presence of spasticity can interfere with several everyday activities and, in particular, when lower limbs are involved, gait disorders are likely to occur [3,5]. Moreover, not only self-reported spasticity levels are predictive of the need for assistive devices to ambulate [2] but the more recent scale established to assess the prospects of the impact of spasticity on people with MS (i.e. Multiple Sclerosis Spasticity Scale, MSSS-88 [6]) includes a specific subscale related to walking problems.

The negative consequences of spasticity are usually managed by integrating pharmacologic and rehabilitative treatments. However, in some cases, although spasticity appears to be significantly attenuated after therapy, the possible correspondent functional improvements are subtler or not detectable at all. This may be partly due to the inadequacy of the clinical scales used to assess spasticity [7], although they remain the most widely used tool in a clinical environment.

To partly overcome the drawbacks associated with the use of scales, a number of biomechanical tests have been proposed to provide objective measures of spasticity, such as the Wartenberg Pendulum Test [8] and the use of powered devices that force a joint to oscillate. In the first case, the swing of the leg (which is released from a full knee extension position and left free to oscillate) is analyzed, assuming that increasing levels of spasticity would decrease the number and amplitude of oscillations. The latter are basically systems in which a joint is mechanically moved while controlling the applied force or the displacements [9] and the stiffness or the frequency of resonance of the joint measured. Nevertheless, although such systems may actually discriminate between different levels of spasticity with a good degree of reliability and repeatability and the results are well correlated with the Modified Ashworth Scale (MAS), [10] there is little evidence of a direct relationship with walking or other functional measures [11].

In recent times, some attempts have been made to extract information about actual effects of spasticity (and related treatments) on gait of individuals with MS by instrumental assessment of spatio-temporal, kinematic and kinetic parameters. Ørsnes et al. [12] tested 14 MS patients with spasticity before and after an 11-day period of baclofen

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http://dx.doi.org/10.1016/j.jns.2015.09.352
0022-510X/

treatment using a treadmill equipped with force platforms. A number of spatio-temporal parameters were analyzed (i.e. stride length, percentages of stance, swing and double support phases) but none of them significantly improved after the treatment, probably owing to small sample size and large inter-individual variations, as hypothesized by the authors. Deterioration of gait kinematics (particularly as regards increased knee flexion at heel strike) and increased activity of leg muscles related to spasticity were observed by Kelleher et al. [13] who employed an optoelectronic system to characterize gait features in people with MS. The perceived impact of spasticity (assessed through the overall rating of the MSSS-88 scale) was found significantly correlated with several spatio-temporal gait parameters (e.g. cadence, velocity, step width and time and double support phase percentage) assessed by means of the GAITRite electronic walkway in a sample of 44 patients with MS, thus suggesting that the impairment of gait quantitatively measured reflects, to some extent, on the self-perception of spasticity impact in everyday activities [14]. Finally, Balantrapu et al. [15] reported that individuals with MS characterized by lower limb spasticity exhibit a poorer performance in walking using ambulatory, kinematic, physiological and perceived measures.

Despite the useful information obtained from these investigations, an analysis of the literature shows that the existing quantitative data on the effect of spasticity on gait are not only scanty, but also somewhat scattered as no analyses that integrate kinematics, kinetics, surface electromyography (EMG) and spatio-temporal parameters have been carried out to date. Three-dimensional quantitative gait analysis, although quite widespread in supporting clinicians' decisions in neurologic diseases such as cerebral palsy, stroke and Parkinson's disease, is still relatively little used for MS, since it is considered expensive, time-consuming and complex to interpret [16–17]. Nevertheless, the use of synthetic indexes such as Gait Variable Score and Gait Profile Score [18], recently validated for MS [19], and successfully applied also in the case of other neurological diseases characterized by the presence of spasticity, such as Cerebral Palsy (CP) [20], allows a reduction of the large amount of kinematic data available from the gait analysis to single values that are easy to understand and simple to use as outcome measures for the assessment of the effectiveness of rehabilitation and pharmacologic treatments.

On the basis of the aforementioned considerations, this study aims to quantitatively and objectively assess the impact of lower limb spasticity on gait in people affected by MS who exhibit relevant levels of spasticity by means of three-dimensional gait analysis from which kinematic, spatio-temporal and muscular activation data can be extracted. Our idea is that in individuals affected by MS, the spastic gait pattern is characterized by specific kinematic and muscular activation features. To test this hypothesis, data from gait analysis will be compared with those of a control group to establish what variables appear most sensitive to the presence of spasticity and thus provide a set of indicators that are most likely to effectively link spasticity to the ambulatory function.

2. Methods

2.1. Subjects

Nineteen patients suffering from relapsing-remitting MS (12 females, 7 males, mean age 54.6 SD 9.5 years) with an EDSS score in the range 3.5–6.5 (mean EDSS 4.4 SD 1.4) and who were referred to the Regional Multiple Sclerosis Centre of Cagliari (Sardinia, Italy) were enrolled in the study after compilation of self-reported questionnaires and a neurological evaluation.

A control group (n = 19, 7 females, 12 males, mean age 47.1 SD 11.4 years, EDSS in the range 2.5–4.5, mean EDSS 3.4 SD 0.7) was established among individuals affected by MS currently followed at the same centre, but with no clinical evidence or self-reported spasticity. The main criteria for inclusion in the study were a diagnosis of MS according to the 2005 McDonald criteria [21], the ability to independently ambulate with or without an assisting device (i.e. cane, crutches or walking frames) for at least 100 m and the absence of any other condition able to affect gait.

EDSS was evaluated for each patient by a MS expert neurologist and the degree of spasticity was self-assessed by participants the day of the laboratory tests using the spasticity Numerical Rating Scale (NRS). The NRS is measured according to the level of spasticity over the preceding 24 h on a 0–10 range, where NRS 0 means “no spasticity” and 10 “the worst possible spasticity” [22].

The main features of the participants are shown in Table 1. The local ethics committee approved the study and all participants signed an informed consent agreeing to participate in the study.

2.2. Kinematic data collection and processing

The acquisition of kinematics associated with the body segments of interest (trunk, pelvis, thigh, shank and foot) as well as the main spatio-temporal parameters of gait (i.e. gait velocity, stride length, step width, cadence, stance, swing and double support phase percentage) was performed using an optoelectronic system composed of eight Smart-D cameras (BTS Bioengineering, Italy) set at a frequency of 120 Hz. Twenty-two spherical retro-reflective passive markers (14 mm diameter) were placed on the skin of individuals' lower limbs and trunk at specific landmarks following the protocol described by Davis et al. [23]. Participants were then asked to walk barefoot at a self-selected speed in the most natural manner possible at least six times on a 10 m walkway, allowing suitable rest times between the trials. The raw data were then processed with the dedicated Smart Analyzer (BTS Bioengineering, Italy) software to calculate the spatio-temporal parameters of gait and the variation of the kinematic parameters of interest within the gait cycle, namely pelvic tilt, rotation and obliquity, hip flexion–extension, adduction–abduction and rotation, knee flexion–extension, ankle dorsiflexion and foot progression. Kinematic data were then summarized separately for each limb using the Gait Variable Score (GVS) and the Gait Profile Score (GPS). This summary measure of gait quality was recently proposed by Baker et al. [18] on the basis of the previously defined Gait Deviation Index. The GPS (expressed in degrees) represents the Root Mean Square (RMS) difference between a patient's data and the mean value obtained from tests performed on the unaffected population calculated for the kinematic variables mentioned above on the whole gait cycle. The RMS difference referring to each of them is defined as the Gait Variable Score (GVS). Higher GVS/GPS scores indicate larger deviations from a hypothetical “normal” gait. Such indexes were found effective in characterizing the gait alterations of MS individuals with a single measure [19].

Finally, the range of motion (ROM) of sagittal plane joints (i.e. hip and knee flexion-extension and ankle dorsiflexion) calculated during the whole gait cycle as the difference between the maximum and minimum value recorded during a trial, was also considered for the analysis.

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

	MS spasticity	MS control group	p-Value
Participants # (M, F)	19 (7 M, 12 F)	19 (12 M, 7 F)	–
Age (years)	54.6 ± 9.5	47.1 ± 11.5	0.058
Height (cm)	162.9 ± 9.3	167.4 ± 8.5	0.066
Body mass (kg)	59.7 ± 12.8	67.9 ± 16.3	0.061
NRS score	7.7 ± 1.3	NA	–
EDSS score	4.4 ± 1.4	3.4 ± 0.7	<0.001*

NA = Not Applicable).
* Denotes statistical difference ($p < 0.05$).

Please cite this article as: M. Pau, et al., Effect of spasticity on kinematics of gait and muscular activation in people with Multiple Sclerosis, J Neurol Sci (2015), http://dx.doi.org/10.1016/j.jns.2015.09.352