Gait & Posture 38 (2013) 51–55

Contents lists available at SciVerse ScienceDirect

Gait & Posture

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

Gait variability and disability in multiple sclerosis

Michael J. Socie [a], Robert W. Motl [b], John H. Pula [c], Brian M. Sandroff [b], Jacob J. Sosnoff [b,*]

[a] Department of Mechanical Science and Engineering, University of Illinois, Urbana, IL, United States
[b] Department of Kinesiology and Community Health, University of Illinois, Urbana, IL, United States
[c] Illinois Neurological Institute, University of Illinois College of Medicine, Peoria, IL, United States

ARTICLE INFO

Article history:
Received 19 June 2012
Received in revised form 4 October 2012
Accepted 20 October 2012

Keywords:
Walking impairment
EDSS
Motor function
Spatiotemporal gait parameters

ABSTRACT

Gait variability is clinically relevant in some populations, but there is limited documentation of gait variability in persons with multiple sclerosis (MS). This investigation examined average and variability of spatiotemporal gait parameters in persons with MS and healthy controls and subsequent associations with disability status. 88 individuals with MS (age 52.4 ± 11.1) and 20 healthy controls (age 50.9 ± 8.7) performed two self-paced walking trials on a 7.9-m electronic walkway to determine gait parameters. Disability was indexed by the Expanded Disability Status Scale (EDSS) and ranged between 2.5 and 6.5. Gait variability was indexed by standard deviation (SD) and coefficient of variation (CV = SD/mean) of step time, step length, and step width. Average gait parameters were significantly correlated with EDSS (ρ = 0.756–0.609) and were significantly different in individuals with MS compared to controls ($p \leq 0.002$). Also, step length ($p < 0.001$) and step time ($p < 0.001$) variability were both significantly greater in MS compared to controls. EDSS was positively correlated with step length variability and individuals with MS who used assistive devices to walk had significantly greater step length variability than those who walked independently (p's $< .05$). EDSS was correlated with step time and length variability even when age was taken into account. Additionally, Fisher's z test of partial correlations revealed that average gait parameters were more closely related to disability status than gait variability in individuals with MS. This suggests that focusing on average gait parameters may be more important than variability in therapeutic interventions in MS.

1. Introduction

Multiple sclerosis (MS) is a neurologic disease that affects an estimated 400,000 American adults and 2.5 million adults worldwide. MS results in demyelination and axonal loss in the central nervous system (CNS). Such CNS damage may result in physical disability (potentially including weakness, sensory loss, and/or ataxia) and gait impairment [1,2]. Disability in MS can be indexed by the Expanded Disability Status Scale (EDSS) [3,4], which is influenced by ambulatory status. EDSS scores range from 0 to 10, where 0 represents no impairment, 4 represents the onset of significant walking impairment, 6 represents onset of assistive device use during ambulation, and 10 represents death due to MS [4]. In addition to the EDSS, which is a clinical standard, disability level in MS has been characterized by use of assistive devices during ambulation [5]. Greater than 50% of individuals with MS require assistive devices within 15 years of disease onset [1].

Gait impairment is one of the most frequent consequences of MS, and walking dysfunction is considered by the majority of patients as the most challenging, life-altering aspect of the disease [6]. Persons with MS walk slower, take shorter, wider, and slower steps, and spend a greater percent of the gait cycle in double-support compared with healthy controls, even early in the disease course [7–9]. Such gait impairment have also been directly associated with disability status as a marker of disease progression [7,10].

Gait variability (i.e. fluctuations in gait parameters between steps) is predictive of mobility impairment and falls in older adults and other neurological populations [11–14]. Movement variability is further associated with health in biological systems and is a marker of motor control function [15,16]. Gait variability might be more sensitive to dysfunction in MS than traditional parameters such as walking velocity [17]. However, we are unaware of research testing that possibility and this is important in forming therapeutic interventions for MS.

There is some evidence that persons with MS have elevated gait variability compared to controls. For example, one study reported that persons with MS exhibit greater kinematic variability at the

* Corresponding author at: Department of Kinesiology and Community Health, University of Illinois at Urbana-Champaign, 301 Freer Hall, 906 S. Goodwin Ave., Urbana, IL 61801, United States. Tel.: +1 217 333 9472, fax: +1 217 244 7322.
E-mail addresses: msocie@gmail.com (M.J. Socie), robmotl@illinois.edu (R.W. Motl), jpula1@uic.edu (J.H. Pula), bsandro2@illinois.edu (B.M. Sandroff), jsosnoff@illinois.edu (J.J. Sosnoff).

0966-6362/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.gaitpost.2012.10.012

hip, knee, and ankle during ambulation than healthy controls [18]. Other studies have reported that persons with MS who had mild impairment demonstrated greater variability of step time and single-support time [8] and step length [17] than controls. Data from a small sample ($N = 10$) indicates that gait variability increases with disability in MS [19]. That study reported that only persons with MS who had walking impairment (EDSS > 4.0) had greater variability of stride length compared to healthy controls, but this could be driven by low statistical power associated with the small sample and should be replicated with a larger sample. Consequently, further documentation of gait variability as a function of disability is a necessary step toward investigating the clinical relevance of gait variability in MS.

This investigation examined average and variability of spatiotemporal gait parameters in persons with MS with a wide range of disability levels and healthy controls as well as associations between average gait parameters, gait variability and disability in persons with MS. We hypothesized that individuals with MS would exhibit greater gait variability than controls. Second, we hypothesized that gait variability would be greater in persons with MS with greater disability. Third, we hypothesized that associations between gait variability and disability would be stronger than associations between average gait parameters and disability in MS.

2. Methods

The procedures for this investigation were approved by a University Institutional Review Board and all participants provided written informed consent prior to data collection.

2.1. Participants

Persons with and without MS participated in this investigation. Inclusion criteria for participants with MS required a neurologist-confirmed diagnosis, the ability to walk without or with an assistive device (e.g. a cane or walker) and be relapse-free for at least 30 days prior to testing. Inclusion criteria for controls required no gait impairment, no assistive device use, and no medical condition causing significant morbidity such as neurological or cardiovascular disease.

2.2. Procedures

Upon arrival at the testing facility, participants with MS underwent an examination by a neurologist to generate an EDSS score [4]. To determine spatiotemporal gait parameters and gait variability, all participants performed two walking trials across a 7.9-m electronic walkway (GAITRite^{TM}, CIR Systems Inc., Haverton, PA, USA) at self-selected, comfortable speed. Participants began walking 1.5 m in front of he GAITRite^{TM} and continued to walk 1.5 m beyond the mat to insure that steady state gait was measured. On average the MS group took 13.3 steps, whereas the control group took 10.7 steps per trial. Use of assistive devices was permitted during testing. Average walking velocity, step length, step time, and step width were recorded. Variability of step length, step width, and step time was indexed by the standard deviation (SD) as well as the coefficient of variation (CV = SD/mean). The SD is operationalized as an absolute measure of variability, whereas CV is operationalized as a relative measure of variability.

Gait parameters were calculated individually for each pass over the walkway; those values were then averaged across trials to produce final values.

2.3. Statistical analysis

Statistical analyses were performed using SPSS software version 19.0 (SPSS Inc., Chicago, IL, USA). Statistical significance was assumed for $p < 0.05$. Group differences in age and gender distribution were determined using an independent sample *t*-test and chi-square test, respectively.

2.3.1. MS vs. controls

Differences in average and variability of gait parameters between individuals with MS and controls were determined using independent sample *t*-test. The magnitudes of group differences were indexed by Cohen's *d* effect sizes [20].

2.3.2. Gait variability and disability

Associations between gait variability and disability level were examined in the context of EDSS as well as assistive device use. Pearson's and Spearman's correlations were performed for average gait parameters, gait variability, age, and EDSS in the MS group. Partial correlations were also performed for gait parameters and EDSS while controlling for age and gender. Differences in gait parameters between individuals with MS who used assistive devices to walk and those who walked independently were determined using a mixed-model ANCOVA while controlling for age and gender.

2.3.3. Average vs. variability parameters

A Fisher's *z*-test was used to determine differences between the strength of correlations between average gait parameters and EDSS compared to gait variability and EDSS.

3. Results

3.1. Participant characteristics

Eighty-eight participants with MS and 20 healthy controls participated in this investigation (Table 1). The MS group had an average age of 52.4 years, average duration of MS of 11.8 years, and median EDSS score of 4.5. 83% of the MS group was female, 32% used unilateral assistive devices (e.g. canes), and 6% used bilateral assistive devices (e.g. walkers). The control group had an average age of 50.9 years and 80% of the group was female. There were no differences between groups in demographic characteristics ($p > 0.05$).

3.2. MS vs. controls

The MS group demonstrated lower walking velocity and step length and greater step time and step width than the control group (Table 2). Step length and step time SD and CV were significantly greater in MS vs. controls ($p < 0.05$). The effect sizes of these differences were moderate to large in magnitude (*d*'s ranged from 0.4 to 1.4). The MS group also had a greater step width SD, but not CV, compared to the control group.

3.3. Gait variability and disability

EDSS was significantly correlated with all average gait parameters, gait variability parameters (except step width SD), and age in the MS group (Table 3). Given that age was correlated with gait variability in our sample and that gait variability has been previously associated with advanced age [12] and gender [21], we examined correlations between EDSS and gait in the MS group while controlling for age and gender. Partial correlations between EDSS and all average parameters and gait variability remained significant in individuals with MS while controlling for age and gender (Table 3).

After controlling for age and gender, individuals with MS who used assistive devices during ambulation had significantly greater

Table 1
Participant characteristics.

Characteristic	MS ($N = 88$)	Controls ($N = 20$)
Age (years)	52.4	50.9
SD	11.1	8.7
Range	30–78	31–62
MS duration (years)	11.8	N/A
SD	9.9	
Range	0–43	
EDSS	4.5	N/A
IQR	3.0	
Range	2.0–6.5	
Gender (% female)	83.0	80.0
Unilateral assist (% users)	31.8	0.0
Bilateral assist (% users)	5.7	0.0

Note: MS, multiple sclerosis; *N*, sample size; SD, standard deviation; EDSS, Expanded Disability Status Scale; IQR, inter-quartile range.