ORIGINAL ARTICLE

Gait Impairments in Persons With Multiple Sclerosis Across Preferred and Fixed Walking Speeds

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ABSTRACT. Remelius JG, Jones SL, House JD, Busa MA, Averill JL, Sugumaran K, Kent-Braun JA, Van Emmerik RE. Gait impairments in persons with multiple sclerosis across preferred and fixed walking speeds. Arch Phys Med Rehabil 2012;93:1637-42.

Objectives: To investigate (1) whether previously observed changes in gait parameters in individuals with multiple sclerosis (MS) are the result of slower preferred walking speeds or reflect adaptations independent of gait speed; and (2) the changes in spatiotemporal features of the unstable swing phase of gait in people with MS.

Design: Cross-sectional study assessing changes in gait parameters during preferred, slow (0.6m/s), medium (1.0m/s), and fast (1.4m/s) walking speeds.

Setting: Gait laboratory with instrumented walkway and motion capture system.

Participants: MS group with mild to moderate impairment (n=19, 16 women) with a median Expanded Disability Status Scale score of 3.75 (range, 2.5–6), and a sex- and age-matched control group (n=19).

Interventions: Not applicable.

Main Outcome Measures: Gait speed, stride length, stride width, cadence, dual support time, swing time, and timing of swing foot and body/head center of mass during swing phase.

Results: Individuals with MS walked at slower preferred speeds with longer dual support times compared with controls. In fixed-speed conditions, dual support times were longer and swing times were shorter in MS compared with controls. Stride width was wider for all speed conditions in the MS group. In fixed-speed conditions, the MS group positioned their head and body centers of mass closer to the anterior base of support boundary when entering the unstable equilibrium of the swing phase.

Conclusions: Longer dual support time is part of a gait strategy in MS that is apparent even when controlling for the confounding effect of slower preferred speed. However, a gait strategy featuring longer dual support times may have limitations if potentially destabilizing swing dynamics exist, which especially occur at walking speeds other than preferred for people with MS.

Key Words: Accidental falls; Gait; Multiple sclerosis; Rehabilitation.

IN MULTIPLE SCLEROSIS (MS), central nervous system signals are disrupted after the myelin sheaths surrounding neurons are damaged by an autoimmune response.[1] MS can affect sensory and motor pathways, leading to diminished perception, vestibular sense, and control of muscles that can disturb balance and coordination.[1-4] This balance disruption can lead to impaired walking ability and reduced mobility, which is ranked as one of the most important factors for maintaining a good quality of life by individuals with MS.[5] The ability to walk is compromised in those with MS, as more than 50% of the MS population experiences falls during activities of daily living.[6] These falls occur despite alterations to gait that may be adopted as part of a protective strategy to increase stability during walking.[7] A protective gait strategy is generally nonspecific, yet is characterized by slower gait speeds and wider strides during walking gait.[8]

Even with mild disability resulting from MS, individuals adapt gait such that they walk with slower preferred speeds, shorter stride lengths, longer dual support times, and altered lower limb kinematics.[7,9-12] Walking speed directly influences parameters of gait, including dual support time, stride length, and cadence.[13,14] As such, it remains unclear whether the changes in gait observed in previous studies of walking by individuals with MS are attributable to slower walking speed or reflect MS-related functional impairments. What is needed is an assessment of the changes in gait parameters in people with MS under controlled speed conditions at speeds other than preferred, to determine whether altered gait patterns reflect adaptations other than walking speed.

When more time is spent with both feet on the ground in dual support, swing foot dynamics intended to hasten the reestablishment of the dual support posture of gait may alter other gait dynamics such that the benefit gained from a longer dual support strategy may be offset, leading to more frequent falls. The unstable equilibrium of swing is defined as the portion of the gait cycle when the whole body center of mass (CoM_{body}) is positioned in front of the base of support formed by the stance foot in the

List of Abbreviations

ANOVA	analysis of variance
B_p	physical boundary (anterior) of the base of support
CoM	center of mass
CoM_{body}	whole body center of mass
CoM_{head}	center of mass of the head segment
EDSS	Expanded Disability Status Scale
FSS	Fatigue Severity Scale
MS	multiple sclerosis
VAFS	Visual Analog Fatigue Scale

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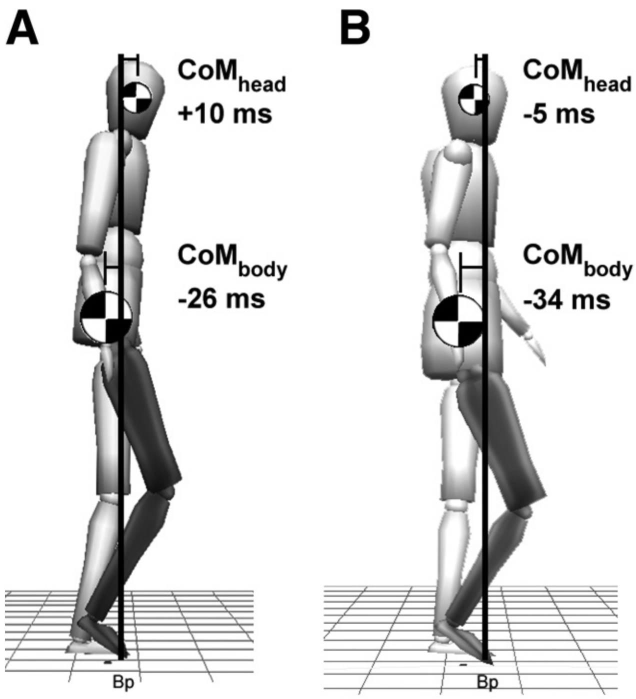

Fig 1. MS (A) and control (B) example postures at physical boundary crossing (B_p) by the swing foot toe while walking at the faster gait speed (1.4 m/s).

anterior-posterior direction.[15] The anterior boundary of the base of support is the toe of the lead stance foot. Walking has been described as a series of controlled forward falls that occur when the body enters an unstable equilibrium during the swing phase.[15] During swing, the CoM_{body} transits beyond the physical boundary (anterior) of the base of support (B_p) (fig 1) and the body enters the unstable equilibrium, which ends when the CoM_{body} is recaptured by a new base of support formed at swing foot heel strike. During the unstable equilibrium, an individual can optimize recovery from gait disturbances by ensuring that the swing foot is among the first segments of the body to move beyond the anterior boundary, thereby keeping the swing foot beneath the body, albeit in the air. Therefore, it is important to understand the relative timing and sequence in which salient segments cross beyond the boundary of the base of support during the controlled anterior fall phase of gait.

The purpose of this study was to determine whether reported changes in gait parameters in people with MS compared with those without MS are the result of slower preferred gait speed or of other MS-related adaptations to gait. Secondly, this study reported on intersegmental dynamics related to the formation of the swing phase of gait. Gait data were collected during preferred and fixed-speed walking trials in a group of individuals with mild to moderate functional limitations resulting from MS and a group of age- and sex-matched non-MS controls. Gait parameters that were assessed included the spatial variables stride length and width, and the following temporal variables: cadence, dual support time, swing time, and intersegmental timings for anterior boundary (B_p) crossings by the CoM_{body} and center of mass of the head segment (CoM_{head}) relative to the swing foot. We hypothesized that if earlier reported changes in gait parameters (dual support and swing times) are only observed at preferred speed, then speed is considered a confounding factor in earlier studies. In contrast, if differences in gait parameters are found in the fixed-speed conditions, then the observed differences in stride parameters may be attributed to MS-related adaptations that are not due to differences in walking speed.

METHODS

Participants

Nineteen volunteers (16 women) with mild to moderate impairment resulting from MS participated in this study (table 1). The MS group evaluated their disability using the self-administered Expanded Disability Status Scale (EDSS)[16] (median, 3.75; range, 2.5–6). None of the participants with MS reported exacerbations of symptoms in the previous 6 months, visual acuity less than 20/200, or were nonambulatory. The distribution of the MS subtypes was primary progressive (n=2), relapsing remitting (n=15), and secondary progressive (n=2). Participants walked unassisted during data collection. The time elapsed since diagnosis ranged from 2 to 26 years (mean ± SD: 10.3±7.8), and participants were taking the following medica-

Table 1: Participant Characteristics and Functional Assessment

Characteristics	MS	Controls	$F_{1,36}$	*P*	95% CI
Age (y)	51.3±10.5	51.8±11.5	0.01	.930	−7.6 to 6.9
Height (cm)	167.6±6.7	164.8±6.7	1.70	.201	−7.5 to 1.6
Body mass (kg)	75.65±16.6	67.39±10.0	4.96	.032	−41.13 to −1.92
Vibration threshold (V)	17.7±13.1	8.9±6.4	6.79	.013	−15.4 to −1.9
Pressure threshold (g)	4.64±10.23	0.65±.70	2.88	.098	−8.76 to 0.78
Fatigue score (VAFS cm)	3.88±2.39	2.33±1.88	6.71	.014	−3.18 to −0.39
FSS	5.6±1.2	2.7±1.1	3.20	<.001	1.9 to 3.9
Foot taps (in 10s)	34.3±9.1	48.4±9.9	17.70	<.001	6.6 to 18.8
Normal speed (m/s)	1.33±.19	1.46±.21	3.79	.059	−0.01 to 0.26
Normal speed (statures/s)	0.799±.123	0.890±.134	4.89	.033	0.008 to 0.178
Normal cadence (steps/min)	111.7±10.4	118.5±11.6	0.01	.065	−14.0 to 0.4
Normal stride length (cm)	1440±18	1480±10	0.63	.431	−29 to 67
Brisk speed (m/s)	1.63±.24	1.91±.27	11.51	.002	0.11 to 0.45
Brisk speed (statures/s)	0.973±.150	1.157±.150	13.56	.001	0.083 to 0.286
Brisk cadence (steps/min)	122.8±14.2	137.7±12.7	1.38	.002	−23.7 to −6.1
Brisk stride length (cm)	1593±26	1661±13	0.94	.339	−35 to 99

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviation: CI, confidence interval.