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Gait variability across the disability spectrum in people with multiple sclerosis

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ABSTRACT

Background: An alternative method suggested to assess changes in walking in people with multiple sclerosis (PwMS) is evaluating gait variability. This is a credible option since gait variability reflects to some degree the quality of gait control.
Objective: Examine the impact of disability on gait variability in PwMS.
Methods: In this cross-sectional study, the data pool was divided into seven levels of disability based on the Expanded Disability Status Scale (EDSS) score, ranging from 0 to 6.5. Gait variability was studied using an electronic mat.
Results: The final analysis included 381 PwMS (249 women); mean age 44.0 years. Non-significant differences were observed between the EDSS subgroups at the lower end of the spectrum (EDSS 0–3.5) in all gait variability parameters. In contrast, PwMS in the EDSS 5.0–5.5 group demonstrated a significant increase in variability of step length (~151%), single support (~93%) and step time (142%) compared with those who scored 0–3.5. Moreover, participants in the EDSS 5.0–5.5 group had elevated step length variability compared to the EDSS 4.0–4.5 group (9.3 (S.E. = 2.2) vs. 5.5 (S.E. = 0.4), *P*-value = 0.005).
Conclusion: We encourage clinicians to follow-up on the gait variability score as it appears to reflect mobility deterioration in PwMS.

1. Introduction

Multiple sclerosis (MS) is an autoimmune disease of the central nervous system causing progressive disability in young adults and affecting an estimated 2.5 million individuals worldwide [1]. In MS, demyelination and axonal loss occur in the central nervous system. Such damage frequently results in gait and balance impairments [2]. Following 45 years of MS, 76% of people with MS (PwMS) require an ambulatory aid and 52% bilateral assistance or worse [3]. For the majority, this dysfunction is considered the most challenging life-changing aspect of the disease [4].

Various studies have examined gait performance in the MS population confirming PwMS walk slower, take shorter steps, have a wider base of support and both legs contact the ground over a prolonged period (double support period) [5–7]. The causes of such gait dysfunction are complex and not completely understood. Factors contributing to mobility disorders in MS may include slowed spinal somatosensory conduction [8], abnormal sensorimotor control [9] and leg power asymmetry [10].

An alternative method that has been suggested to assess changes in walking in people with multiple sclerosis (PwMS) is evaluating gait variability. This is a credible option since gait variability reflects to some degree the quality of gait control [11]. Previous investigations performed in the elderly and other neurological populations have shown that gait variability was associated with a slower walking speed, increased falls, fear of falling [12–14], subclinical brain vascular abnormalities [15] higher energetic costs [16] and reduced motor control [17,18].

Compared to standard measures of gait, relatively few studies have examined gait variability in the MS population [19–22]. Several reports have shown that PwMS have greater gait variability compared with healthy adults, demonstrated in short and long distance walks. Socie et al. (2013) reported an increase in step length variability in PwMS who ambulated with an assistive device compared to those who walked independently [19]. In contrast, Lizrova Preiningerova, et al. found that gait variability was stable between disability levels in 125 PwMS [22]. Therefore, the characteristics of gait variability in the MS population are still unclear. Interestingly, increased gait variability has clinical significance in PwMS. Socie et al. (2011) demonstrated that recurrent fallers (i.e. 1 + falls/year) with MS exhibit greater variability of spatial footfall placement than non-fallers with MS [23].

However, questions remain as to the impact of disability on gait variability in PwMS. For instance, most previous studies did not divide gait

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variability scores according to the neurological impairment level which can ascertain whether and to what extent, gait variability had progressed throughout the disease process. Moreover, is there a specific MS disability group with a high incidence of elevated gait variability? Furthermore, is variability equally demonstrated in all gait parameters (e.g. step, length, step time, step width)?

New information as to these queries can be beneficial for professionals involved in physical rehabilitation in the MS population and may stimulate new and improved rehabilitation strategies aimed at increasing gait stability. Furthermore, gait variability may be an improved parameter to detect walking deterioration in PwMS compared to traditional gait measures.

Therefore, the objective of the current study was to examine the variability of major spatio-temporal parameters of gait in a relatively large group of PwMS. The data pool was divided into seven levels of disability based on the Expanded Disability Status Scale (EDSS) score.

2. Methods

2.1. Study design and participants

This study was an observational cross-sectional study comprising 381 PwMS, 249 women and 132 men, from the Multiple Sclerosis Center, Sheba Medical Center, Tel-Hashomer, Israel. Inclusion criteria included: (1) a neurologist-confirmed diagnosis of definite MS according to the revised McDonald criteria [24]; (2) <7.0 on the EDSS [25], equivalent to the ability to walk at least 20 m without resting; and (3) relapse-free for at least 30 days prior to testing. Exclusion criteria included: (1) orthopedic disorders that could negatively affect mobility; (2) major depression or cognitive decline preventing walking on a treadmill; (3) pregnancy; (4) blurred vision; (5) cardiovascular disorders; (6) respiratory disorders; (7) or taking steroids or fampridine. The study was approved by the Sheba Institutional Review Board. All participating subjects signed an informed consent form for use of their data in the research projects.

2.2. Gait analysis

Gait variability was studied using the GAITRite™ system version 4.0.3 (CIR Systems, Inc. Haverton, PA, USA), which consisted of a 4.6 m long electronic walkway containing 2304 compression-sensitive sensors arranged in a grid pattern. As the subject ambulates across the walkway, pressure is exerted by his feet, thus activating the sensors. Simultaneously, targeted software utilized special algorithms to automatically group the activated sensors and form footprints. The system integrates all footprints and provides the following spatio-temporal parameters: velocity, cadence, step/stride length, step/stride time, heel to heel base of support, swing/stance time, single/double time and percentage according to gait cycle.

In the present study, we extracted the variability of step length, step time, single support and step width expressed by the coefficient of variation (CV) (CV = SD/mean). The CV (%) is operationalized as a measure of relative gait variability [26]. These parameters were selected in line with previous studies demonstrating their relevance in gait difficulties in the neurological population.

A single valid walking trial was defined once the participant independently walked at his self-selected speed across the electronic mat in one direction without stopping. Each participant performed six consecutive walking trials. Gait variability parameter scores were individually calculated for each pass. The values from all trials were then averaged to produce the final results. The integrity of the data registry was evaluated by a computerized logic-algorithm-questioning process identifying data entry errors. Measurements were performed at the Center of Advanced Technologies Rehabilitation Center, Sheba Medical Center Tel-Hashomer, Israel. Gait measures were collected by a physical therapist specialized in neurological rehabilitation.

2.3. Expanded disability status scale (EDSS)

The EDSS, an accepted method of quantifying disability in MS, consists of an eight-function system scale monitoring motor, sensory, cerebellar, brain stem, visual, bowel and bladder, pyramidal and other functions. Each domain is graded from 0 = no disability to 5 or 6 = maximal disability [25]. According to the score achieved from each functional system, an integrated score between 0 = normal examination and 10 = death from MS is derived. A score ranging from 1.0 to 4.5 denotes patients who are fully ambulatory without aid; a score from 5.0 to 7.5 reveals moderate to severe impairment in ambulation. An EDSS level of 6.0 is primarily defined by the need for a unilateral aid for walking at least 100 m; an EDSS level of 6.5 is defined by the need for a bilateral walking aid; and a score from 8.0 to 9.5 refers to PwMS essentially restricted to bed.

PwMS were divided into seven levels of disability based on their EDSS score. As the half step on the EDSS scale at EDSS levels 1.0 to 5.5 does not represent a significant difference in disability, we assigned groups with different EDSS scores: an EDSS score under 1.0, EDSS scores of 2.0–2.5, 3.0–3.5, 4.0–4.5, 5.0–5.5 and 6.0–6.5 (using a walking aid).

2.4. Statistics

Descriptive statistics determined the demographic and clinical characteristics of the study participants according to their level of neurological impairment. Gait variability parameter data were normally distributed according to the Kolmogorov–Smirnov test. Differences in gait variability parameters between PwMS subgroups were determined using the analysis of variance (ANOVA) tests. Post-hoc Bonferroni adjustment enabled multiple comparisons between EDSS subgroups. All analyses were performed using SPSS software (Version 21.0 for Windows, SPSS Inc. Chicago, IL, USA). All reported *P*-values were two-tailed. The level of significance was set at $P < 0.05$.

3. Results

The mean EDSS for the entire study group was 2.9 (SD = 1.8, median = 2.5, IQR (25%, 75%) = 1.5, 4.0), mean disease duration was 6.3 (SD = 7.4) years and mean age 44.0 (SD = 12.5). In terms of EDSS categories, the scores of the pyramidal, cerebellar and sensory divisions were 1.7 (SD = 1.3), 1.0 (SD = 1.1) and 1.0 (SD = 1.0), respectively. No differences were observed between the MS patient subgroups in terms of height (*P*-value = 0.854), body mass (*P*-value = 0.341) and gender ratio (*P*-value = 0.491). As expected, age and disease duration increased from the lower to the higher EDSS subgroups. The individuals' characteristics and neurological assessment scores are summarized in Table 1.

In terms of velocity, the self-selected walking speed was slower in patients with higher disability compared to patients with lower disability. Nonetheless, there was no significant difference between the groups at the lower spectrum of the EDSS scale (0–3.5). MS patients with an EDSS score of 4.0–4.5 demonstrated a significant decrease in walking speed (~15%) compared with those who scored in the EDSS 0–3.5 range (*P*-value < 0.001). Additionally, PwMS with walking aids (i.e. EDSS 6–6.5) walked significantly slower compared to all other disability groups. PwMS with an EDSS score of 6–6.5 walked slower (~47%) compared to people with a low disability (EDSS 0–3.5).

Gait variability scores for the total sample pool are provided in Table 1. Table 2 demonstrates the significant values between all EDSS subgroups. Non-significant differences were observed between the EDSS subgroups at the lower end of the spectrum (EDSS 0–3.5) in all gait variability parameters. In contrast, MS patients with an EDSS score of 4.0–4.5 demonstrated a significant increase in variability of the step time (~75%) and single support period (~92%) compared with those who scored in the EDSS 0–2.5 range (*P*-value < 0.001). In