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Gait termination in individuals with multiple sclerosis

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ABSTRACT

Despite the ubiquitous nature of gait impairment in multiple sclerosis (MS), there is limited information concerning the control of gait termination in individuals with MS. The purpose of this investigation was to examine planned gait termination in individuals with MS and healthy controls with and without cognitive distractors. Individuals with MS and age matched controls completed a series of gait termination tasks over a pressure sensitive walkway under non-distracting and cognitively distracting conditions. As expected the MS group had a lower velocity (89.9 ± 33.3 cm/s) than controls (142.8 ± 22.4 cm/s) and there was a significant reduction in velocity in both groups under the cognitive distracting conditions (MS: 73.9 ± 30.7 cm/s; control: 120.0 ± 25.9 cm/s). Although individuals with MS walked slower, there was no difference between groups in the rate a participant failed to stop at the target (i.e. failure rate). Overall failure rate had a 10-fold increase in the cognitively distracting condition across groups. Individuals with MS were more unstable during termination. Future research examining the neuromuscular mechanisms contributing to gait termination is warranted.

1. Introduction

Multiple sclerosis (MS) is a disease of the central nervous system impacting over 2.5 million people worldwide [1]. It results in a heterogeneous array of symptoms including impairments in sensorimotor functioning, cognition, balance and gait [2–5]. Gait impairments in MS are often characterized by a decline in gait speed, reduced step length and cadence compared with controls [6,7]. The majority of research on MS and gait impairment focuses on continuous gait tasks such as the six-min walk test and 25 foot walk test [8,9]. Although these performance tasks provide information regarding gait in general, they provide minimal information regarding the control of subtasks of gait, such as starting and stopping, that are essential for effective locomotion.

Coming to a stop from walking (i.e. gait termination) is a fundamental component of locomotion [10,11]. It is a necessary skill for avoiding obstacles and maintaining balance when transitioning from walking to standing [11]. From a motor control perspective, maintaining posture during gait termination is potentially more challenging than maintaining posture during continuous walking due to larger destabilizing forces that are incurred when transitioning from dynamic to static posture [12,13]. This postural transition has the potential to lead to falls in populations at a high risk of falling, such as MS [11]. Indeed, in individuals with MS transfers and ambulated-related activities are the two most cited actions that are performed at the time of a fall [14].

Gait termination is dependent on two distinct control strategies. First, a macro control strategy requires planning proper foot placement in order to terminate gait at a desired target [13]. Second, a micro control strategy involves continuous control of the body center of mass (COM) inside the stability boundary as the feet are placed in the desired location [13]. Deficits in gait termination can result from difficulties with either of these control strategies and have been observed in clinical populations including individuals with cerebellar ataxia and peripheral neuropathy [15,16]. Given the similarity in gait impairment between these pathologies and individuals with MS [6,17,18], it is logical to speculate that individuals with MS will have impairments in gait termination.

Furthermore, gait subtasks such as gait termination are rarely done in isolation but rather under more complex conditions of divided attention. Although there is evidence that continuous walking [19], gait initiation [20,21] and static balance control [22] under attentional distracting conditions are impacted in persons with MS, there is no data related to gait termination in this context. It is logical to speculate that a cognitive distraction could impede an individual's ability to execute a complex motor task, such as gait termination.

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The purpose of this study was to examine planned gait termination in individuals with MS compared to healthy age matched adults during normal conditions and cognitively distracting conditions. Based on the high prevalence of gait impairments in individuals with MS, we hypothesized that they would demonstrate greater impairments in gait termination compared to age matched adults. Specifically it was predicted that they would have higher task failure rates and be more unstable during stopping. Additionally, under cognitively distracting conditions, gait termination performance would decrease in both groups with greater deficits observed in individuals with MS compared to controls.

2. Methods

2.1. Participants

This cross-sectional analysis included a convenience sample of twenty-five individuals with MS who participated in a fall prevention trial (ClinicalTrials.org #NCT01956227) [23]. Inclusion criteria included a neurologist-confirmed diagnosis of MS, relapse free for the previous three months, the ability to walk with or without an assistive device, and having experienced a fall in the previous year. Medication use was not collected and consequently did not impact inclusion or exclusion from the study. All measures for the current analysis were completed during a single assessment. Additionally, the study included a control group of thirty adults similar in age and gender composition to the MS group. Recruitment of participants happened through fliers posted in the community and email advertisements to the university community. Prior to enrollment in the study, control subjects were screened to confirm the absence of neurological and musculoskeletal conditions along with any medications that might interfere with gait or cognitive functioning.

2.2. Procedure

All procedures for the investigation were approved by the University of Illinois at Urbana-Champaign's institutional review board. After arriving at the testing facility, all participants were given a verbal explanation of study procedures, an informed consent document, and the opportunity to ask questions about the study. After providing written informed consent, the participants completed demographic questionnaires and multiple walking trials.

All participants provided demographic information including age and gender. Participants with MS also provided self-reported MS subtype, disability level and years since diagnosis. Self-reported disability was assessed with the self-administered Kurtzke questionnaire [24].

Participants completed four 5 m walking trials starting and stopping on a 6 m Zeno™ pressure sensitive walkway (Fig. 1). Participants were instructed to stand in the starting zone and begin walking after hearing an auditory cue. Participants were instructed to stop walking when they reached the stop zone. Starting and stopping zones were indicated by cones. During the first two trials, participants walked normally, and during the last two trials, participants completed a simultaneous cognitive task (i.e. dual task). For the added cognitive task, participants listed alternating letters of the alphabet from a given starting point (e.g. M, O, Q), and this task has been applied in MS [25]. No explicit task prioritization instructions were given to participants.

2.3. Data analysis

Maximum walking velocity was determined for each trial and the average for each unique condition for each participant was calculated. Gait termination was quantified with two distinct measures. First, in order to evaluate the macro control strategy, a global measure of success or failure was determined. Gait termination was successful if the participant stopped with both feet inside the designated gait termination zone (Fig. 1). The gait termination zone was 26.6 cm long by 61.0 cm wide and was identified in data analysis by exported pressure sensor data form the Zeno™ walkway. The active pressure sensors for each walking trial were examined to determine if the participant stopped within the gait termination zone.

Second, in order to evaluate the micro control strategy, the time needed for the center of mass estimate (COMe) to stabilize during the stopping phase of gait termination was determined [13,16]. The COMe was determined by the ProtoKinetics™ Movement Analysis Software based on the shift patterns of footfalls and values of pressure sensor activations over time, described in the software's measurements manual. Two gait termination stabilization time measures were reported, a raw measure of gait termination stabilization time (GTST) reported in seconds and a gait termination stabilization time normalized to maximum gait velocity ($GTST_{norm}$). GTST was measured from first heel contact in the gait termination zone until COMe velocity in the anterior-posterior (AP) plane returned to baseline value. Baseline AP COMe velocity was the average AP COMe velocity during 4 s of quiet stance prior to the initiation of each trial. Only successful gait termination trials were included in the stabilization time analysis. GTST was determined for forty-two trials (84%) for the MS group and 57 trials (95%) in the control group. Given that gait velocity was expected to be higher in controls compared to the MS group and that gait velocity impacts available response time to stabilize during gait termination [11,26,27], GTST was normalized to the maximum walking velocity of the trial, reported as $GTST_{norm}$. This was done by dividing the GTST by the maximum gait velocity for each trial.

2.4. Statistics

All statistical analyses were performed in SPSS Statistics 22.0 (IBM Inc., Armonk, NY). Descriptive statistics were computed for all demographic and gait termination outcome measures. Independent samples *t*-tests and chi-squared tests were used to determine

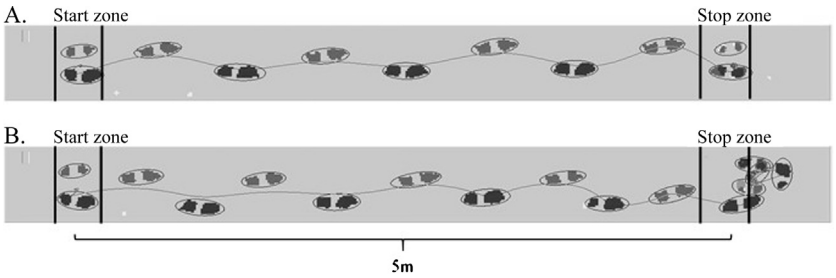

Fig. 1. Participant with multiple sclerosis footfalls and center of mass estimate trajectory during (A) a successfully terminated trial and (B) a trial in which they failed to terminate their gait within the stop zone.