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Dual-task interference during gait on irregular terrain in people with Parkinson’s disease

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ABSTRACT

Background: Gait impairments in people with Parkinson’s disease (PD) are accentuated in dual-task conditions. Most PD studies on dual-task gait have measured only straight line walking and treadmill gait. Gait alterations on irregular terrain are poorly understood.
Research question: To what extent does walking on irregular terrain exacerbate dual-task interference in people with PD, compared to age-matched control participants?
Methods: Gait data were collected for nine participants with mild to moderate PD and nine healthy age-matched participants on regular and irregular terrains. Gait was tested as a single task and in dual-task conditions with serial 7 subtractions. The spatiotemporal variables (speed, cadence, single limb support, step length and width), kinematic variables (range of motion for hip, knee and ankle joints) and stability variables (trunk range of motion and center of mass acceleration RMS) were compared across conditions.
Results: People with PD showed reduced gait speed and cadence and increased mediolateral center of mass acceleration when walking on irregular terrain with dual-tasks. Surface irregularity was associated with increased ankle transverse motion in both groups. Increased hip and knee sagittal motion was observed in the control participants when terrain changed from regular to irregular under dual-task conditions. This was not statistically significant for the PD group.
Significance: Dual-task walking on irregular terrain exacerbated the gait deficits, particularly for people with PD. Gait speed, cadence and mediolateral body stability were compromised when people with PD walked on irregular terrain whilst performing dual-tasks. There was an increase in ankle transverse motion in both groups when traversing irregular terrain. This might have been an adaptive strategy, to prevent tripping.

1. Introduction

Gait impairments and balance limitations are common among people with Parkinson’s disease (PD) [1–3]. Some of the characteristic features of PD gait include a stooped torso and shuffling steps, as well as slowness [3]. Additionally, scuffs at mid-swing and reduced ground clearance are also common [1,4].

Most PD gait analyses have been conducted on smooth, solid surfaces [5,6], whereas studies relevant to outdoor walking environments that require greater postural control and increased foot clearance are scarce. Past studies have revealed a correlation between age and impaired balance [7,8]. Sensory-motor input impairments in older adults have been identified as causing balance challenges when navigating irregular terrain [7,9,10]. Even healthy older adults show a more conservative gait pattern on irregular terrain with decreased walking speed, step length, trunk and head variability, and increased step variability [7,8,11]. Previous research has reported that people with PD demonstrate reduced toe clearance and increased mediolateral head motion when walking on a foam surface [12]. Other research has shown that the ability to adapt gait termination on slippery terrain is limited for people with PD due to shorter step length and greater step width [13,14].

In addition to these findings, research has shown that when adding a secondary performance task (i.e., dual-task) while walking, gait deficiencies increase in those with PD [6,15–17]. People with PD often exhibit a reduced gait speed, shortened step length, and increased gait variability under dual-task conditions during walking on smooth, solid surfaces [15,16]. Performing a concurrent task while walking results in

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a deterioration of performance in one or both activities due to the neurological and muscle dysfunction characteristic of PD [15,17]. The amount of interference is dependent on several factors, such as individual characteristics, disease severity, task type and complexity, and the overall environmental challenge [6].

Morris et al. recommended that people with PD should avoid dual-task performance during walking [18]. However, other studies have reported improvements in stride length and walking speed following multi-task training for PD [15]. This is encouraging, as skill acquisition obtained from performing dual tasks while walking can improve dual-task performance in other activities [15,19].

The main purpose of this study was to evaluate gait alterations on irregular terrain in people with PD under dual-task conditions. Two different surfaces (regular and irregular terrains) and tasks (single-task and dual-task) were evaluated. Specifically, we hypothesized that i) the ability for dual-task gait adaptations would be reduced in people with PD from regular terrain to irregular terrain; ii) the gait deficits on irregular terrain would be amplified under dual-task conditions compared to single-task conditions in people with PD; and iii) the gait adaptations would be different between people with PD and the control participants on irregular terrain under dual-task conditions.

2. Methods

2.1. Participants

Nine people with mild to moderate PD (4 females and 5 males) and nine healthy age-matched controls (3 females and 6 males) were recruited from the Rehabilitation and Wellness Clinic in the Physical Therapy Department at the University of Utah. PD participants had a diagnosis of PD as defined by the UK Parkinson’s Disease Brain Bank Criteria. Disease severity was determined using the Unified Parkinson's Disease Rating Scale (UPDRS) and the Hoehn & Yahr (H&Y) scored by the treating neurologist (Table 1). Participants were contacted by telephone to establish interest in participating and to ascertain if they could meet the following inclusion criteria: i) 50 years of age or older; ii) no medical condition or injury that might affect the ability to participate; iii) no self-reported balance problems in the control participants as described using the Activities-specific Balance Confidence (ABC) scale [20]; and, iv) ability to ambulate without the use of a mobility aid in people with PD. The University of Utah Institutional Review Board approved this study (IRB 52667) and all participants consented.

2.2. Protocol

Two 40 cm x 60 cm force plates (Bertec, Columbus, OH, USA) were placed flush with the surface of a raised 0.76 m x 7.3 m walkway. The walkway was supported by a series of five adjustable jacks on both sides and provided fore/aft and cross-slope capabilities. The irregular terrain was made of 0.05 m thick polyurethane faux rock panels (Model R3-RV-PN-MT, Regency River Rock, FauxPanels.com) designed to simulate an uneven cobblestone walkway. These rock panels were secured to the wooden walkway for the irregular terrain and removed from the walkway for the regular terrain. The rock panels on the force plates were isolated from the surrounding panels in order to prevent any forces outside the force plate from being read [21] (Fig. 1a–b). In order to minimize the risk of injury, a fall protection harness and overhead rail was integrated into the study.

Table 1
Mean (standard deviation) participants demographics.

	Age (years)	Height (m)	Weight (kg)	UPDRS score	H&Y score
PD (n = 9)	67.7 (7.1)	1.66 (0.16)	81.0 (20.6)	36.1 (11.8)	2.39 (0.33)
Control (n = 9)	67.7 (8.0)	1.69 (0.05)	74.5 (5.6)	N/A	N/A

2.3. Data acquisition

Trials were performed on regular and irregular terrains at self-selected speeds. To ensure an on-medication state during the activities for people with PD, all data collection was performed within 1–3 h of taking anti-Parkinsonian medication. Regular and irregular terrains were randomized for each trial, with three successful trials collected on each terrain. Success was defined as a clear heel strike on each force plate. Participants walked on the walkway several times prior to data collection to familiarize themselves with each surface. This procedure improved the probability of a successful trial and reduced gait adjustments. Three-dimensional motion data were collected using a 24-camera motion capture system (NaturalPoint, Corvallis, OR, USA). Participants were fitted with tight clothing and instrumented with 76 reflective markers based on a modified Helen Hayes marker set. The marker trajectories and ground reaction forces were recorded at 100 Hz and 1000 Hz with a fourth-order low-pass filter at 6 Hz and 20 Hz, respectively.

2.4. Dual-task

The cognitive task was serial 7 subtractions [22]. For the dual-task trials, the researcher first selected a random starting number between 50 and 100 and then asked participants to perform subtractions of 7 from that initial number as many times as possible while walking. In order to prevent a learning effect, different randomly selected starting numbers were chosen for each trial.

2.5. Gait measurement

Major gait events (i.e., heel strike and toe off) were defined via force plate activation with a 20 N threshold. The gait parameters of interest were calculated using Visual 3D software (C-Motion, Germantown, MD, USA). The spatiotemporal variables included speed, cadence, step length, step width and single limb support. Step length and width were normalized to leg length, and single limb supports were normalized to gait cycle. Computed lower body kinematics included the range of motion (RoM) between the minimum and maximum joint angles for the hip, knee and ankle joints in all three body planes.

Trunk-related variables were used as direct measures of stability in this study for two reasons: first, kinematics play a large role in maintaining stability; second, trunk center of mass (CoM) acceleration variability is associated with balance control [7]. The stability variables included trunk RoM in all three body planes and CoM acceleration root mean square (RMS) in anteroposterior (AP), mediolateral (ML) and vertical directions. The RMS of trunk CoM was normalized to gait speed [7].

2.6. Statistical analysis

Data were analyzed using SPSS 20.0 software (IBM Corporation, Armonk, NY, USA). Descriptive statistics were calculated for spatiotemporal, kinematic and stability variables. A Shapiro-Wilk’s test confirmed the normality of these data. In order to investigate gait adaptations on irregular terrain under dual-task conditions for people with PD, paired *t*-tests were used to compare the dual-task performance on irregular terrain with two other conditions separately, which were the dual-task performance on regular terrain and single-task performance on irregular terrain. In order to determine the gait adaptation under dual-task conditions between groups, independent *t*-tests were used to compare the dual-task performance between people with PD and control participants on the regular and irregular terrains, respectively. The

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