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A little trouble getting started: Initial slowness in Parkinson's disease step negotiation

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ABSTRACT

Bradykinesia is a prominent problem for persons with Parkinson's disease (PD) and has been studied extensively with upper extremity tasks; however there is a lack of research examining bradykinesia in targeted lower extremity tasks related to mobility. Navigating steps and curbs are challenging tasks for older adults and neurologically impaired and thus utilizing these behaviors provides ecological validity to the study of bradykinesia. Herein we assess differences in step negotiation performance between individuals with PD and aged matched older adults. Three-dimensional kinematics and ground reaction forces were collected while 12 participants with PD and 12 older adults performed a single step up onto a platform. Persons with PD spent a significantly greater amount of time in the heel lift phase ($P = 0.0003$, $d = 1.80$). Peak vertical foot velocity of the lead foot was also significantly less in PD ($P = 0.02$, $d = 1.05$). Lastly, persons with PD displayed reduced sagittal hip and knee range of motion during the trail step ($P = 0.01$, $d = 1.20$ and $P = 0.02$, $d = 1.05$, respectively). Parkinson's participants exhibited slight decrement in step negotiation execution. Increased step time and decreased foot velocity and range of motion were attributes associated with Parkinson's step negotiation performance. Contrary to our hypothesis, in many comparisons, persons with PD during their best medicated state performed comparable to older adults, indicative of successful pharmacotherapy. Rehabilitation efforts can seek to improve performance in motor control tasks such as step negotiation, by restoring the relationship between perceived and actual motor output and enhancing muscle coordination and output as well as ranges of motion.

1. Introduction

Bradykinesia, or slowness of movement, is one of the cardinal manifestations of Parkinson's disease (PD) and has been studied extensively using upper extremity reaching tasks [1,2]. Collectively, the findings from past research have illustrated decreased hand velocity and increased movement time in persons with PD compared to healthy controls [1]. Similarly, when comparing ON and OFF medication, persons with PD demonstrated increased task duration time and decreased peak reaching velocity in their OFF medicated state compared to their ON medicated state [2]. There is a paucity of investigations, however, evaluating deficits and differences in movement caused by bradykinesia during targeted lower extremity movements in PD.

Movement control abilities are known to be different between upper and lower extremities. For example, force control accuracy has been shown to be greater during upper extremity task versus lower extremity tasks [3]. Impairments in lower extremity performance may significantly impact many activities of daily living and reduce independent mobility. For example, the ability to maneuver over obstacles in the path of progression without loss of balance is essential for maintaining an independent lifestyle. Because steps and curbs are some of the most frequent locations for tripping and falls [4], investigation of a single step negotiation task has functional relevance for a mobility impaired population such as PD. Previous literature investigating single step negotiation techniques in healthy older adults found they displayed increased double stance phase duration, greater anterior trunk flexion, greater hip flexion, and reduced ankle dorsiflexion compared to healthy young adults [5]. However, it is unknown how single step negotiation performance may be further impaired in PD.

The purpose of this study was to examine kinematic and temporal characteristics of single step negotiation in persons with PD. We hypothesized persons with PD would exhibit bradykinesia-related motor deficits, such as increased task duration and decreased peak foot velocity. Improving our understanding of the biomechanical limitations or alterations in movement patterns during step negotiation for persons with PD may facilitate intervention and rehabilitation efforts.

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2. Methods

2.1. Subjects

Twelve participants with PD (8 males, age (mean ± SD) 64 ± 9 years, height 1.71 ± 0.07 m, mass 77 ± 10 kg, Unified Parkinson's Disease Rating Scale (UPDRS) motor score in best medicated state 27 ± 7, Hoehn and Yahr 2.5 ± 0.5, Mini-Mental State Examination (MMSE) 29 ± 1) and twelve age-matched older adults (7 males, age 65 ± 7 years, height 1.71 ± 0.11 m, mass 74 ± 18 kg) were recruited to participate in this study.

The study was limited to ambulatory patients who had a clinical diagnosis of idiopathic PD by a fellowship trained movement disorders neurologist with Hoehn and Yahr disability rating of mild to moderate. Age-matched controls had no history of PD diagnosis and were within one year of their PD equivalent. Participants were excluded if they had a history of cardiovascular, musculoskeletal, vestibular, or other neurological disorder, as well as a previous orthopedic surgery. None of the participants had experienced a lower-extremity orthopedic injury within the last year. None of the participants reported they used an assistive device. Persons with PD were tested during their self-reported period of maximal therapeutic benefit (approximately 1–1.5 h after their last dose of antiparkinsonian medication). We chose to evaluate stepping behavior in the medicated state because most activities of daily living occur during a normal medication cycle and any deficits identified would be targeted during rehabilitation occurring in the medicated state.

2.2. Procedures

All procedures were explained and consent was obtained as approved by the Institutional Review Board. Kinematic data were collected using a ten-camera, three-dimensional motion analysis system (Vicon Motion Systems, Centennial, CO, USA) at a sampling frequency of 120 Hz. Ground reaction forces were obtained using floor embedded force platforms (Bertec Corporation, Columbus, OH, USA) at a rate of 360 Hz. Thirty-five passive reflective markers were placed in accordance with the Vicon Plug-In Gait full body model. Participants were instructed to stand on the force platform and perform a single step up with their dominant leg (leg they would kick a soccer ball with [6]) onto a 15 cm high x 36 cm wide step located directly in front of them and positioned on a force platform. Participants remained standing in a static position once both feet were atop the step. Trials were deemed successful if participants maintained balance throughout the trial and stepped fully with both feet coming to rest on top of the platform.

2.3. Data analysis

Kinematics and kinetic data were time synchronized and filtered using fourth-order low-pass Butterworth filters with cutoff frequencies of 10 Hz. The step task was broken into four phases which are described in detail in Fig. 1. These time intervals were chosen based on previous step negotiation literature [5] and are clinically relevant because gait initiation is composed of multiple motor programs which coincide with these gait events [7,8]. Heel strike and toe off were identified for each trial using vertical ground reaction force data from the force platform.

Peak vertical and horizontal foot velocity were calculated using the lateral malleoli marker. Vertical foot clearance was calculated using the vertical distance between the second metatarsal head marker and the height of the platform. Maximum and minimum angles were used to find the range of motion for each of the four phases during the single step task. Anticipatory postural adjustments were calculated using center of pressure measurements [9].

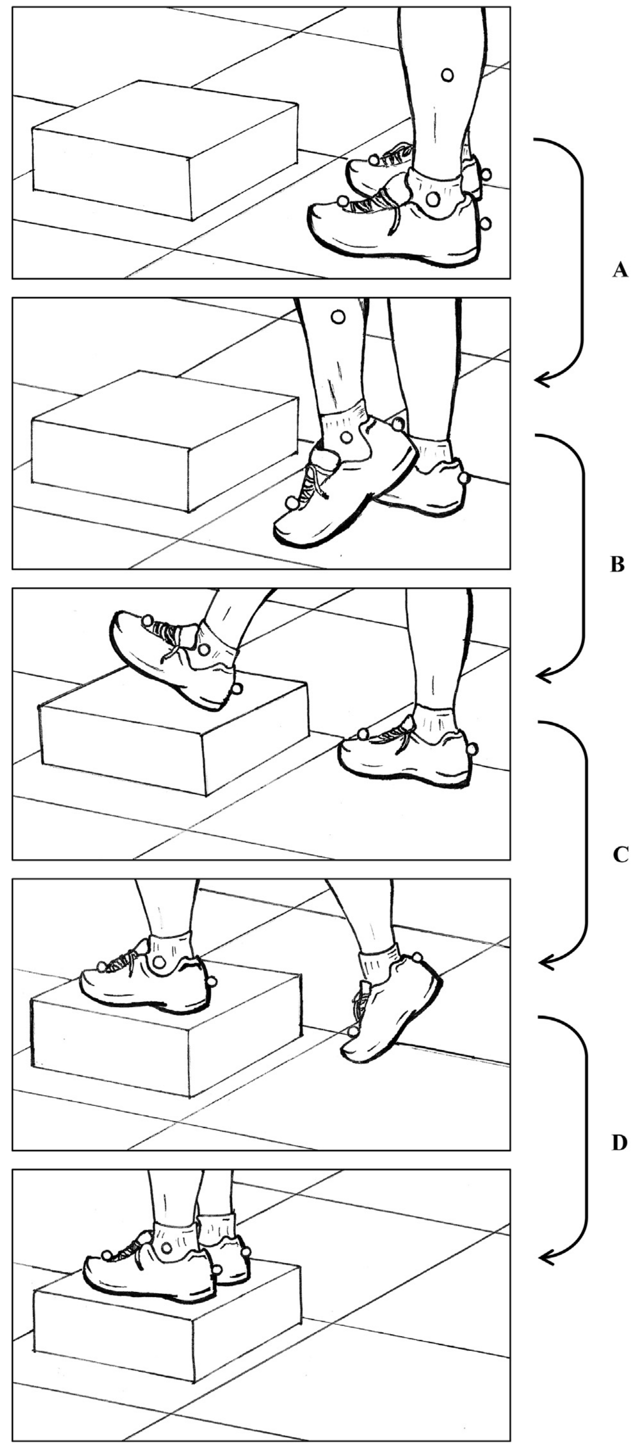

Fig. 1. The step negotiation task was broken into four phases: A. *Heel Lift*: heel off of first foot to toe off of first foot; B. *Lead Step*: toe off of first foot to heel strike of first foot on platform; C. *Double Stance*: heel strike of first foot on platform to toe off of second foot; and D. *Trail Step*: toe off of second foot to heel strike of second foot on platform.

2.4. Statistical analysis

Descriptive statistics for age, mass, height and body mass index (BMI) were calculated for both groups. In the PD group, the dominant limb was the more affected limb for all except one participant. Independent samples *t*-tests were used to determine if significant differences existed in the dependent variables of interest between the two populations ($P \leq 0.05$) using SPSS (SPSS 21, SPSS Inc., Chicago, IL, USA). P-values were not corrected for multiple comparisons based on a