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Lecture

Gait alterations on irregular surface in people with Parkinson's disease

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ABSTRACT

Background: Persons with Parkinson's disease are at high risk for fall-related injuries with a large proportion of falls occurring while walking, especially when the walking environments are complex. The aim of this study was to characterize gait parameters on irregular surface for persons with Parkinson's disease.
Methods: Three-dimensional gait analysis was conducted for nine persons with Parkinson's disease and nine healthy age-matched adults on both regular and irregular surfaces. Repeated ANOVA and paired *t*-test were performed to determine the effect of surface and group for spatiotemporal, kinematic and stability variables.
Findings: Individuals with Parkinson's disease showed a larger ratio of reduction for speed, cadence and step length than controls when the surface changed from regular to irregular. The ankle transverse range of motion and root mean square of trunk acceleration increased on irregular surface for both groups. Additionally, individuals with Parkinson's disease demonstrated a decreased knee sagittal range of motion and trunk frontal and transverse range of motion compared with controls, especially on the irregular surface.
Interpretation: The irregular surface posed a greater challenge to maintain balance and stability for individuals with Parkinson's disease. A relatively small knee range of motion in the sagittal plane and large root mean square of trunk acceleration increased the potential fall risk for individuals with Parkinson's disease. This information improves the understanding of parkinsonian gait adaptations on irregular surfaces and may guide gait training and rehabilitation interventions for this high fall-risk population.

1. Introduction

Parkinson disease (PD) is second only to Alzheimer disease in prevalence as a neurodegenerative disease affecting 3.3% of individuals over 65 years of age (De Lau and Breteler, 2006; Rocha et al., 2014). Diagnosis of PD is often performed through observing the presence of bradykinesia in combination with rigidity, tremor and/or gait instability (Pahwa and Lyons, 2014). Characteristic PD gait includes a stooped torso and shuffling steps that are the result of overall reduced flexion and extension in the legs and nonzero velocity in the feet at the time of heel strike (Samii et al., 2004). In addition, scuffs at midswing are known to occur. Heel strikes are often replaced with flat foot initial contact, and steady state gait is achieved after several strides instead of just two or three as is sufficient for able-bodied gait (Roiz et al., 2010). Furthermore, the task of turning is often characterized by a series of small shuffled steps instead of a pivot movement exhibited by a healthy population (Hong et al., 2009).

Approximately 70% of falls experienced by older adults take place during the task of walking (Berg et al., 1997). Persons with PD have particularly high fall risk in comparison to healthy older adults. Some studies report that 60–80% of persons with PD fall each year compared with 30% of community-dwelling older adults (Ashburn et al., 2008). The observed postural sway patterns are different for persons with PD. They display larger medial-lateral as well as anterior-posterior movement of the center of pressure during gait, which are generally thought to be indicative of the postural instability and movement deficits in PD (Horak et al., 2005; van Wegen et al., 2001). More specifically, medial-lateral instability which usually occurs when the motion of body center of mass (CoM) exceed the boundary of base of support (Rogers and Mille, 2003), is particularly threatening because it could increases the lateral fall risk, which is more likely to result in hip fractures than falls in other directions (Dargent-Molina et al., 1996). Additionally, persons with PD also exhibited a fear of falling and the most related factor was walking difficulties (Franchignoni et al., 2005).

The complexity of walking environments encountered, such as irregular surfaces, increase fall risk, especially in persons with PD due to the poor performance in executive function, which is important to safely navigate challenging environments (Jahanshahi et al., 2000).

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Previous studies have also revealed a correlation between postural imbalance and sensory-motor impairments associated with the aging population (Deshpande et al., 2006; Marigold and Patla, 2008). Healthy elderly individuals showed a more conservative walking pattern with reduced walking speed and step length, but increased step time variability when walking on irregular surfaces (Marigold and Patla, 2008; Menz et al., 2003a).

To our knowledge, no studies have reviewed the effect of irregular surfaces on the gait of persons with PD. As irregular surfaces may increase fall risk and lateral falls are prevalent and severe with aging (Dargent-Molina et al., 1996; Gray and Hildebrand, 2000; van Wegen et al., 2001), it is beneficial to investigate the gait adaptations in this population on different surfaces. The aim of this study was to characterize gait parameters on irregular surfaces for persons with PD. Specific hypotheses include: (1) the gait of persons with PD would be different on the regular surface versus the irregular surface, where irregular surface was defined by cobble stone; (2) the gait of persons with PD is different from age-matched adults on regular and irregular surfaces. The knowledge gained from this study provides additional information for fall prevention and intervention programs for this high fall-risk population. More specifically, these data will be used to develop a training program for persons with PD in a virtual reality environment using the Treadport Active Wind Tunnel system developed at the University of Utah (Hollerbach et al., 2001).

2. Methods

2.1. Experimental set-up

Nine persons with mild to moderate PD (4 females and 5 males) and nine healthy age-matched (HA) controls (3 females and 6 males) were recruited from the Rehabilitation and Wellness Clinic in the Physical Therapy Department at the University of Utah (Table 1). The participants met the following inclusion criteria: 1) 50 years of age or older, 2) have no medical condition or injury that might affect the ability to participate, 3) the healthy subjects have no self-reported balance problem, 4) the persons with PD do not require the use of a mobility aid. Institutional review board approval was obtained and all participants reviewed and signed an informed consent document.

Two 0.4 m × 0.6 m force plates (FP4060-08, Bertec, Columbus, OH, USA) were imbedded to be flush with the surface of a raised 0.76 m × 7.3 m walkway, which was supported by ten adjustable actuators. The irregular surface was simulated using faux rock panels (Regency River Rock, FauxPanels.com). The sections of the panels which fell over the force plates were isolated to effectively prevent contact outside of the boundaries of the force plates to eliminate transfer of ground contact forces (Xu et al., 2016) (Fig. 1). The panels were rigidly affixed to the walkway and the section of panel which covered the force plates were attached to the force plate surfaces, so they could be switched between regular and irregular surfaces. In order to minimize the risk of injury during walking, a fall protection system was also integrated into the experimental setup to prevent injury in the event of a fall, and consisted of an overhead track with trolley, hand rails and a body worn harness.

Table 1
Mean (standard deviation) PD and HA groups characteristics.

	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 (0.31)
HA (n = 9)	67.7 (8.0)	1.69 (0.05)	74.5 (5.6)	N/A	N/A

Abbreviations: UPDRS = Unified Parkinson's Disease Rating Scale; H&Y = Hoehn and Yahr.

2.2. Data acquisition

Walking trials were performed on both regular and irregular surfaces at self-selected speeds and, in the case of persons with PD, commenced one hour after taking anti-Parkinsonian medication in order to ensure an ‘on’ state during the activities. The order of regular and irregular surfaces was randomized for each participant and three successful trials were collected for each condition. A successful trial was defined as one which involved a heel strike by a foot as it was isolated on the specific force plate. Before data collection, subjects walked the length of the walkway several times to be familiar with the different surfaces and specific starting lines were established to achieve successful trials without adjusting their gait. Three-dimensional marker trajectory data were recorded using AMASS (C-Motion; Germantown, MD, USA) at 100 Hz 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. This marker set defined 8 segments which included the feet, legs, thighs, pelvis, and combined head, arms, and trunk segment. Ground reaction forces were measured at 1000 Hz with two force plates. The marker trajectory and analog data were post processed using the software Visual3D (C-Motion; Germantown, MD, USA) and filtered with a fourth-order low-pass Butterworth filter at 6 Hz and 20 Hz respectively to reduce the noise in the signals.

2.3. Gait parameters

Three gait cycles were chosen from each successful trial. Major gait events (heel strike and toe off) were defined via force plate activation with a 20 N threshold and the events off the force plates were determined by the “Automatic gait events” function in Visual3D. Once all of the events were marked, the spatiotemporal parameters were calculated, including speed, cadence, step length, step width, single and double limb supports. Step length and width were normalized to leg length, and single and double limb supports were normalized to gait cycle.

The joint kinematics were also of particular interest in this study and calculated using the “Model based calculation” function in Visual3D. Lower limb kinematic variables included the range of motion (RoM) in degrees between the minimum and maximum joint angles for the hip, knee and ankle joints in three body planes.

The trunk kinematics play a large role in maintaining stability and trunk CoM acceleration variability is also associated with balance control (Marigold and Patla, 2008). As such, trunk-related measurements were used as the more direct measures of stability and determined by the “Model based calculation” function in Visual3D. The trunk/stability variables included the trunk RoM in three body planes and root mean square (RMS) of trunk acceleration in three axial directions. The RMS of trunk acceleration was normalized to gait speed (Marigold and Patla, 2008).

2.4. Statistical analysis

Statistics were performed using SPSS 20.0 (IBM Corporation, Armonk, NY, USA). Descriptive statistics were calculated for gait variables. Two-factor repeated measures analysis of variance (RANOVA) was used to determine the effects of surface (regular and irregular) which was a within-subject factor, and group (PD and HA) which was a between-subject factor. Post-hoc tests were performed using Tukey-LSD test for pairwise comparison. Paired t-test was used to compare between regular and irregular surfaces for both PD and HA groups. The results were considered statistically significant when $P < 0.05$.