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Research report

Obstacle circumvention and eye coordination during walking to least and most affected side in people with Parkinson's disease

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ABSTRACT

Background: The mechanisms that contribute to gait asymmetry in people with Parkinson's disease (PD) are unclear, mainly during gait with greater environmental demand, such as when an obstacle is circumvented while walking.
Objective: The aim of this study was to investigate the effects of obstacle circumvention of the least and most affected side on motor and gaze behavior in people with PD under/without the effects of dopaminergic medication.
Methods: Fifteen people with PD and 15 matched-control individuals were instructed to walk along a pathway, at a self-selected velocity, and to circumvent an obstacle, avoiding contact with it. Each participant performed five trials for each side. Kinematic parameters, mediolateral and horizontal body clearance to the obstacle, strategy to circumvent the obstacle, and gaze behavior were calculated. Parameters were grouped according to the side that the obstacle was circumvented and compared by three-way ANOVAs.
Results: Both people with PD and the control group presented asymmetry to circumvent an obstacle during walking, however this was exacerbated in people with PD. Individuals with PD presented safe strategies (largest mediolateral and horizontal body clearance to the obstacle, "lead-out" strategy, and higher number and time of fixations on the obstacle) during obstacle circumvention for the least affected side compared to the most affected side. In addition, positive effects of dopaminergic medication on body clearance, spatial-temporal parameters, and gaze behavior were evidenced only when the obstacle was circumvented to the least affected side.
Conclusions: The obstacle circumvention to the most affected side is risky for people with PD.

1. Introduction

Obstacle circumvention is a more complex task than unobstructed walking. The former task requires that the individual detects the obstacle's position and edges, performs precise motor actions, and adjusts their movement around it, allowing adequate personal space (body clearance) at the point of moving past the obstacle to ensure safe navigation [1]. During obstacle circumvention, both people with Parkinson's disease (PD) and neurologically healthy individuals decrease step length and step velocity compared to unobstructed walking [2]. In addition, people with PD increase gait variability and duration of gaze fixations on the obstacle and ground when walking with obstacle circumvention, and reduce body clearance without effects from dopaminergic medication [2].

The planning and adjustments to circumvent an obstacle are according to the side of obstacle circumvention [3]. Previous studies have indicated that younger adults when performing circumvention of an obstacle during walking on the non-dominant side increase their personal space [3]. Preservation of body clearance to the obstacle is used as a control criterion by the locomotor system to plan motor adaptations, which is adjusted according to time required to acquire visual information and plan for upcoming hazards [3,4]. Circumvention of an obstacle to the non-dominant side seems to present slower information processing [5] that causes impairments (i.e. asymmetry) in the

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acquisition and use of visual information [6] to make motor adjustments during the task. These impairments may be exacerbated in people with PD [7] who present symptoms manifestation more severely on one side [10–12] of the body from early stage of the disease [13–18]. Asymmetrical degeneration of dopaminergic neurons in the substantia nigra [19], enlarged lateral ventricle contralateral to the more symptomatic side [20], and cognitive disruption often consistent with the symptomatic hemisphere [21] may explain the higher effects in most affected side in people with PD. In addition, dopaminergic treatment has been established to improve gait motor patterns for both side of the body [13,22], although levodopa has a greater effect on the most affected side [23,24]. However, no previous studies have investigated the effects of side to obstacle circumvention on body clearance to the obstacle, gait parameters and gaze behavior in people with PD.

The aim of this study was to investigate the effects on motor and visual behavior of obstacle circumvention during walking to the least and most affected side in people with PD, under and without the effects of dopaminergic medication. We analyzed the body clearance to the obstacle, circumvention strategy, spatial-temporal parameters, and gaze behavior during obstacle circumvention to both sides in people with PD and neurologically healthy individuals (control group). The hypotheses of this study were: i) people with PD would present safe strategies (increase body clearance, stride length and velocity and number of fixations on the obstacle) during obstacle circumvention to the side least affected by the disease compared to other side (most affected side) due to higher impairments presented in most affected side [13–18]; ii) dopaminergic medication would have a positive effect on body clearance, spatial-temporal adjustments and gaze behaviors (increase these parameters) for both sides during obstacle circumvention in people with PD, as indicated previously in a study with obstacle avoidance [22].

2. Materials and methods

2.1. Participants

Fifteen people with idiopathic PD and 15 matched-neurologically healthy individuals (control group) were selected to participate in the study. The participants with PD were referred to the current study by local neurologists. The diagnosis of the disease was performed by an expert neurologist according to the UK Brain Bank Criteria [27,28]. The groups were matched by age, gender, body weight, and height (Table 1).

The following exclusion criteria were established: disease stage above 3 on the Hoehn & Yahr scale [29,30], signs of dementia, a history of orthopedic or vision problems that would make it impossible to perform the experimental protocol. In addition, the inclusion criterion was the people with PD had to be taking PD medication. The study was approved by the local Ethics Committee (CAAE: 45435615.7.1001.5398). All participants gave their signed and written consent to all experimental procedures.

2.2. Experimental protocol

The individuals with PD performed the tasks in the OFF-medication state (after a minimum of 12 h withdrawal from PD medication), and then again 1 h after the participants had taken their dopaminergic medication (ON-medication state); if the individuals were taking dopaminergic agonist medication, they were evaluated after a minimum of 24 h withdrawal from medication. The control group performed the protocol only once.

2.3. Clinical evaluation

Participants with PD were evaluated by an expert researcher through anamneses (historical clinical, cognitive, and medication), the motor portion of the Unified Parkinson's Disease Rating Scale – UPDRS [31], and the H&Y (stage of disease). In addition, cognitive aspects were analyzed using the Mini Mental State Exam [32,33] in all participants.

In addition, for people with PD, motor UPDRS items 20, 21, 22, 23, 25, and 26 were used to assess appendicular asymmetry [14]. The most severely affected limb was determined by finding the difference between the scores for the right and left limbs in the aforementioned UPDRS items. Then, the values of this item-analysis were summed. When this calculation resulted in a positive value, the right limb was the most severely affected limb, but when negative values were obtained, this indicated that the left limb was more severely affected. For the control group, footedness was assessed by asking the participant to kick a ball at a target [21,23]. The limb used to kick the ball was considered as the dominant limb.

2.4. Obstacle circumvention during gait

The participants were instructed to walk along a pathway (approximately 8.5 m long by 3.5 m wide), at a self-selected velocity, and to circumvent an obstacle, avoiding contact with it. In addition, participants were instructed to return to the starting line. The obstacle was cylindrical (0.35 m diameter) and 1.30 m high [2]. The obstacle was positioned in the middle of the pathway, allowing a similar space on both sides (~1.60 m) and 4 m from the starting point. In all trials, the participant was positioned lined up with the obstacle.

Each participant performed 5 circumventions for each side (10 trials in total). The participants were not instructed as to which side they needed to circumvent the obstacle. They chose the side until they had performed 5 trials for one side (e.g., right). Then, the researcher obstructed this side, necessitating that the participants circumvent the obstacle on the other side (e.g., left).

2.5. Data analysis

The kinematic parameters were recorded by an 8 cameras Vicon Motion System® (Bonita System Cameras) with a sample rate of 100 samples/s. Passive reflective markers were placed on the participants' skin at predefined landmarks according to the Plug-in-Gait Full Body model (Vicon) (left and right front and back head, 7th cervical vertebrae, 10th thoracic vertebrae, clavicle, sternum, middle of the right scapula, left and right shoulder, left and right upper arm, left and right elbow, left and right forearm, left and right wrist bar thumb and pinkie side, left and right fingers, left and right anterior and posterior superior iliac spine, mid-way between the posterior superior iliac spines, lateral epicondyle of the left and right knee, left and right lower lateral 1/3 surface of the thigh, left and right lateral malleolus, left and right lower lateral 1/3 of the shank, left and right second metatarsal head and left and right calcaneous) and four markers were placed on the obstacle. Data were filtered using a 5th order low-pass digital Butterworth filter (zero-lag) with a cutoff frequency of 6 Hz.

The data were recorded in two phases of obstacle circumvention: the approach phase − final stride before circumvention of the obstacle; and circumvention phase − stride during the obstacle circumvention (Fig. 1). Nexus software (Vicon) calculated the tridimensional center of mass (CoM) coordinates based on the tridimensional coordinates of the 39 markers, which defined a 15-segment model [34]. Following CoM coordinates, we calculated the mediolateral body clearance (largest mediolateral distance of the CoM to the obstacle during obstacle circumvention) [35,36] (solid arrow in Fig. 2C) and the horizontal body clearance (distance at which participants started to circumvent the obstacle. To calculated this parameter, first it was drawn an imaginary line between the CoM position where participant began the trial and the marker positioned centrally in the top of the obstacle. So, the begin of deviation was defined as five standard deviations of this line) (dashed arrow in Fig. 2C). In addition, the following spatial-temporal parameters of gait for each phase were calculated: stride length, stride