

Case report

Rotating treadmill training reduces freezing in Parkinson disease: Preliminary observations

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Abstract

Two subjects with Parkinson disease (PD) who had difficulty turning, and freezing of gait triggered by turning, participated. Subjects completed four blocks of turning trials. Three blocks were conducted in the absence of treadmill intervention. Both subjects had consistent freezing across blocks prior to training and evidenced more freezing when turning left than right. The final block of turns was performed after 10–15 min of training leftward turning on a rotating circular treadmill. Following training: (1) neither subject froze during leftward turns, (2) muscle activity normalized, and (3) turning times decreased for leftward turns.

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1. Introduction

Many individuals with Parkinson disease (PD) experience difficulty turning and freezing of gait that can lead to falls. Falls during turning are 8 times more likely to result in hip fracture than falls during straight walking [1] and individuals with PD are 3.2 times more likely to sustain a hip fracture than people of similar age without PD [2]. The cost of care for hip fractures in PD is approximately \$192 million per year [2,3]. Given the substantial personal and financial costs associated with this problem, it is clear that strategies are needed to address turning difficulties in order to reduce falls and fractures.

In previous work, we have proposed the use of a rotating treadmill to address difficulties with freezing and turning in individuals with PD [4]. Following stepping in-place on a rotating treadmill, control subjects asked to walk in a straight line without vision will inadvertently turn in circles [5]. This response, called podokinetic after-rotation (PKAR), represents an adaptation to the treadmill stimulus.

The rotating treadmill may be an excellent tool for gait rehabilitation in PD. We have demonstrated that kinematic

patterns employed during PKAR following exposure to the rotating treadmill are similar to those used in voluntary turning [4]. Furthermore, we have shown that people with mild PD are able to adapt to walking on the rotating treadmill and demonstrate robust PKAR [6]. This latter finding is crucial because successful rehabilitation is dependent on the individual's ability to adapt and modify behavior with treatment. The purpose of the present study was to gather preliminary data on the effects of rotating treadmill training in individuals with advanced PD who have freezing of gait and difficulty with turning. We hypothesized subjects would show reduced freezing during turning following a period of training on the rotating treadmill.

2. Methods

2.1. Subjects

We recruited 13 patients with PD who reported having consistent freezing with turns, but only 2 of the 13 people recruited demonstrated consistent freezing in our laboratory setting. Both of these subjects had a long history of PD and substantial on-period freezing, i.e., freezing that occurs despite taking medication. This freezing was triggered by turning in both subjects. These two subjects with idiopathic PD were tested approximately an hour after the first morning dose of their normal medications. Subject demographics are provided in Table 1. This study

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Table 1
Subject characteristics

	Subject 1	Subject 2
Age (years)	66	60
Gender	M	M
Duration of PD (years)	13	17
UPDRS motor subscale score ^a	30.5	31
UPDRS gait score	2	1
Hoehn & Yahr stage	3	2
Medications	Sinemet, Sinemet CR	Sinemet, Pramipexole, Benzotropine

^aDetermined while on medication.

was approved by the Human Studies Committee of the Washington University School of Medicine, and subjects provided informed consent prior to participation.

2.2. Data collection

Each subject completed four blocks of turning trials. Each block included 20 in-place turns, 10 leftward and 10 rightward, of 180° amplitude and 10 trials, 5 leftward and 5 rightward, of the Timed Up & Go (TUG) [7]. The TUG requires the subject to start from a seated position and the examiner times how long it takes the subject to stand up, walk to an object 3 m away, turn around, walk and sit back in the chair. Three consecutive blocks were conducted in the absence of the treadmill intervention to determine consistency of performance across blocks and the potential influence of practice on performance. The fourth block of turns was performed after rotating treadmill training. During rotating treadmill training, subjects walked in place on the perimeter of the rotating treadmill which has a diameter of 122 cm (Neuro Kinetics, Inc., Pittsburgh, PA). Subject 1 walked for 10 min and Subject 2 for 15 min on a disk rotating clockwise at 45°/s. Walking on a rotating treadmill that turns in the clockwise direction results in a PKAR response of turning to the left. Both subjects had more difficulty turning to the left and that is why we chose to train leftward turning using the clockwise-rotating treadmill. Subjects walked for as long as they were able, up to 5 min, and were given rests as needed until they had accumulated 10 or 15 min, respectively, of total treadmill time. For more detailed information on experimental setup, refer to Hong et al. [6].

During trials of turning, we recorded surface EMG from the vastus lateralis bilaterally and foot positions were recorded with a motion capture system (Motion Analysis Corporation, Santa Rosa, CA) using reflective markers placed on the first metatarsal and calcaneus bilaterally. EMG and kinematic data were synchronously sampled at 1000 and 100 Hz, respectively. Kinematic data were used to identify freezing episodes which were defined as coming to a complete stop in the transverse plane in the midst of an ongoing turn. TUG trials were timed with a stopwatch. Leftward and rightward turns were alternated for all turning and TUG trials.

2.3. Data analysis

Number of trials on which at least one freeze occurred was tabulated for each block. DataPac 2K2 (Run Technologies, Mission Viejo, CA) was used for kinematic and EMG analysis. All signals were digitally low-pass filtered at 20 Hz (4th order, zero-lag Butterworth filter). Turn onsets were automatically identified using the vertical coordinate of the toe markers via a threshold criterion method. After placing an event at a threshold of 10 mm, the first derivative of the toe marker in the vertical coordinate was determined and the onset event repositioned to the time just prior to the

threshold when the rate of change increased from zero. Each marked onset was visually confirmed. EMG signals were root mean square averaged with a time constant of 10 ms. Burst onsets and offsets were defined at a threshold of three standard deviations above baseline and were visually confirmed. Bursts that began up to 500 ms prior to turn onset were included in the analysis. Burst durations of the bilateral vastus lateralis muscles were averaged within trials and across trials turning in the same direction. Therefore, burst durations for leftward turns were averaged separately from those for rightward turns. We calculated coactivation indices for the left- and rightward turns separately. Taking the left vastus lateralis as the reference muscle, we calculated the percentage of the burst duration of the left vastus lateralis muscle that had overlapping activity with the contralateral vastus lateralis. This was calculated for every burst and averaged across bursts within trials and across same direction turning trials.

3. Results

Prior to training, subjects demonstrated consistent turning performance across consecutive blocks and evidenced no practice effect. The number of freezing trials when turning leftward for consecutive blocks was 10/10, 10/10, and 9/10 for Subject 1 and 5/10, 4/10, and 6/10 for Subject 2. Fig. 1A illustrates a single trial of turning to the left before training for Subject 1. Note the two periods of freezing marked by asterisks. During these freezes, the left foot remained flat on the floor and the right toe remained on the floor while the right heel moved up and down. There was high amplitude, rapid bursting activity of the vastus lateralis bilaterally. This muscle activity was characterized by coactivation of the left and right vasti during freezes rather than alternating activity between the left and right sides.

Following training neither subject froze during leftward turns, the direction of turning trained. Fig. 1B illustrates a single trial of turning to the left after training in Subject 1. There was no freezing and muscle bursts were of lower amplitude and longer duration. The time to execute this turn was much lower than the time to execute the same turn prior to training.

Pooled data across multiple trials and across subjects demonstrated decreased variability in vastus lateralis burst durations after training when turning to the left. Mean burst durations for leftward turns, before and after training, were 688 ± 455 (mean $\pm$ S.D.) and 894 ± 174 for Subject 1 and 479 ± 394 and 811 ± 263 for Subject 2. The group means for leftward turning were 583 ± 425 ms before training and 852 ± 218 ms after training. Mean burst durations for rightward turns, before and after training, were 675 ± 385 and 869 ± 413 for Subject 1 and 531 ± 304 and 751 ± 230 for Subject 2. The group means for rightward turning were 603 ± 345 ms before training and 810 ± 322 ms after training. After training mean burst durations increased for both left- and rightward turns however, the variability only decreased for the leftward turns.

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