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Asymmetrical pedaling patterns in Parkinson's disease patients

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ABSTRACT

Background: Approximately 1.5 million Americans are affected by Parkinson's disease (Deponti et al., 2013) which includes the symptoms of postural instability and gait dysfunction. Currently, clinical evaluations of postural instability and gait dysfunction consist of a subjective rater assessment of gait patterns using items from the Unified Parkinson's Disease Rating Scale, and assessments can be insensitive to the effectiveness of medical interventions. Current research suggests the importance of cycling for Parkinson's disease patients, and while Parkinson's gait has been evaluated in previous studies, little is known about lower extremity control during cycling. The purpose of this study is to examine the lower extremity coordination patterns of Parkinson's patients during cycling.

Methods: Twenty five participants, ages 44–72, with a clinical diagnosis of idiopathic Parkinson's disease participated in an exercise test on a cycle ergometer that was equipped with pedal force measurements. Crank torque, crank angle and power produced by right and left leg were measured throughout the test to calculate Symmetry Index at three stages of exercise (20 W, 60 W, maximum performance).

Findings: Decreases in Symmetry Index were observed for average power output in Parkinson's patients as workload increased. Maximum power Symmetry Index showed a significant difference in symmetry between performance at both the 20 W and 60 W stage and the maximal resistance stage. Minimum power Symmetry Index did not show significant differences across the stages of the test. While lower extremity asymmetries were present in Parkinson's patients during pedaling, these asymmetries did not correlate to postural instability and gait dysfunction Unified Parkinson's Disease Rating Scale scores.

Interpretation: This pedaling analysis allows for a more sensitive measure of lower extremity function than the Unified Parkinson's Disease Rating Scale and may help to provide unique insight into current and future lower extremity function.

1. Introduction

Parkinson's disease (PD) (Deponti et al., 2013) affects nearly 1.5 million Americans with medical treatment costs approaching $25 billion annually. According to current models of basal ganglia function, changes in the pattern and rate of neuronal activity in the basal ganglia result in a decrease in motor cortical activation in PD patients (Holtbernd and Eidelberg, 2012). This decreased motor activation may limit PD patients' ability to generate and coordinate voluntary movements, including gait and postural stability. Postural instability and gait dysfunction are two of the four cardinal motor symptoms of PD which include bradykinesia, resting tremor, rigidity and postural instability and gait dysfunction. Clinical evaluation of postural instability and gait dysfunction involves examining balance and walking patterns through subjective assessment using the Unified Parkinson's Disease Rating Scale (UPDRS) (Bloem et al., 1998; Schrag et al., 2006). Postural instability and gait dysfunction are rated in this exam on a scale from 0 to 4, with higher scores indicating greater deficits. These deficits affect activities of daily living and may necessitate assistive walking devices to compensate for loss of lower extremity and postural control. Despite postural instability and gait dysfunction having significant impact on activities of daily living and quality of life, the UPDRS postural instability and gait dysfunction measures only comprise two out of the eighteen Motor-III assessment questions (Muslimovic et al., 2008; Schrag et al., 2000). This suggests that not all factors of postural instability and gait dysfunction are assessed during the UPDRS exam.

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Pedaling, like walking, is a bipedal motor task, with both activities requiring the same principles of lower extremity coordination and rhythmic pattern generation (Brown and Kukulka, 1993; Ting et al., 2000; Yang and Stein, 1990; Zehr et al., 2007). Due to the similarities of these tasks, it is reasonable to suggest that dysfunction or asymmetry present in one of these activities may also be present in the other. Therefore, the quantification of pedaling kinetics, which allows for a more precise measure of lower extremity function than the two assessment questions on the UPDRS, in a clinical population with gait impairments may be useful for clinicians in the determination of postural instability and gait dysfunction. Cycling kinetics, which have not been used traditionally as a clinical diagnostic tool for neurological disorders such as PD, are not well documented in any disease population, despite the fact that cycling is often recommended for rehabilitation or exercise in neurological populations (Fowler et al., 2007; Lennon et al., 2008; Pontichtera-Mulcare, 1992; Quaney et al., 2009; Studenski et al., 2005). Pedaling kinetics during cycling has been well described for young, healthy populations (Bini et al., 2010; Carpes et al., 2008; Ericson et al., 1986; Lee et al., 2001; Too and Landwer, 2001). While this is valuable in efforts to improve cycling efficiency in athletes, this data can also serve as normative data for comparative analysis within clinical populations as well. The identification and characterization of deviations from the typical pedaling motion could be beneficial in assessing lower extremity function in individuals with movement impairments. Understanding pedaling kinetics in these disease populations may be useful in tracking disease progression, measuring intervention efficacy, or lending insight into specific areas of function to be targeted for intervention. Recently, we have shown that a "forced-exercise" intervention, delivered via stationary tandem bicycle, resulted in a significant improvement in global motor functioning of PD patients (Ridgel et al., 2009). In this initial study, pedaling kinetics was not quantified although it would have been useful to determine lower extremity function and possible alteration.

Lower extremity asymmetry and how it relates to postural instability and gait dysfunction have not yet been studied in a PD population. The primary metric of interest in PD pedaling kinetics is the symmetry of power output during pedaling. During one pedaling revolution, each limb provides a maximal torque at approximately 100° when the leg is pushing on the pedal (downstroke), through which it powers the motion of the bicycle. This maximal torque is contraposed by the opposite leg generating a smaller and negative torque, when the leg is effectively "pulling up" the other pedal (upstroke) (see Fig. 1). In order to quantify the pedaling motion, this maximum and minimum generated torques, along with the average torque generated for each revolution, must be measured, and the outputs from each limb during the same revolution are then able to be compared using a Symmetry Index (SI). These SI values provide insight into the pedaling coordination of the maximum and minimum outputs and of the average level of function during each revolution.

Power output of the lower extremity, which is directly related to crank torque, is an indicator of cycling performance (Vautier et al., 1995). This relationship allows for identification of lower extremity asymmetries through examination of crank torque produced during pedaling. Healthy individuals, including both recreational and competitive cyclists, exhibit some degree of interlimb asymmetry, ranging from five to twenty percent, during pedaling (Sanderson, 1990) with the dominant leg applying greater torque. Though these asymmetries are present, studies have shown that they become less pronounced as pedaling rate increases from 60 rpm to 80 rpm (Sanderson, 1990), from 40 rpm to 100 rpm (Daly and Cavanagh, 1976), and from 60 rpm to 120 rpm (Smak et al., 1999). These previous studies suggest that while some low extremity asymmetries may be the norm, they are not great enough to affect normal daily activity.

Despite the prevalence of pedaling kinetics characterization in healthy adults, pedaling kinetics in clinical populations such as PD has received relatively little attention. The aim of this project was two-fold: 1) characterize the pedaling kinetics in PD patients during a maximal effort graded exercise test (GXT); and, 2) assess the relationship between measures of pedaling kinetics and clinical measures of gait and postural stability. It was hypothesized that pedaling asymmetries would be found in PD patients, to a similar degree as found in healthy populations, and that these asymmetries would show positive association with clinical measures of gait and postural stability, with worsening clinical ratings corresponding to increased cycling asymmetry.

2. Methods

2.1. Participants

Twenty five participants, (males $n = 11$; females $n = 14$) ranging from 44 to 72 years of age, with a clinical diagnosis of idiopathic Parkinson's disease and who were Hoehn and Yahr stage II–III when off anti-parkinsonian medication were eligible to participate (see

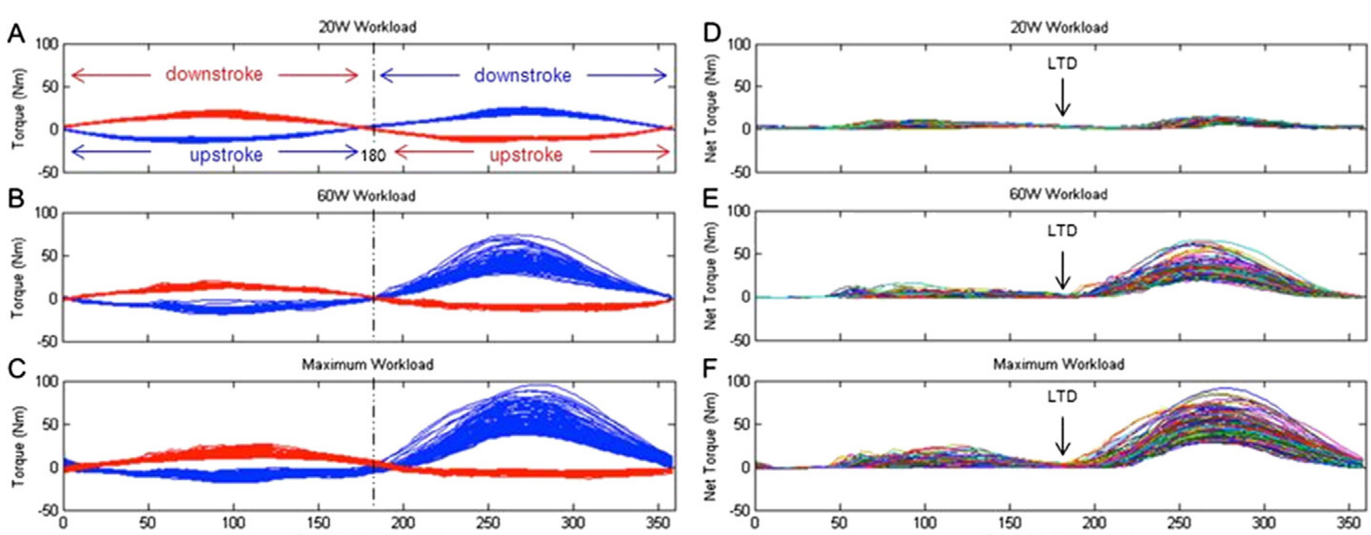

Fig. 1. Example plots of one participant's individual leg torque profiles (A–C; affected side in red and unaffected side in blue) and net torque profiles (D–F) for all pedal revolutions during 20 W (A & D), 60 W (B & E), and maximum (C & F) workloads. The area of low torque duration (LTD) is also displayed in the net torque profiles.