

## Effects of Auditory Cues on Gait Initiation in Patients With Parkinson's Disease: A Preliminary Study

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### Abstract

The purpose of this study was to investigate the effects of auditory cues in the form of a metronome on gait initiation (GI) in Parkinson's disease (PD). 2 patients (mean age: 54 yrs) with idiopathic PD participated in the study. All patients (Hoehn and Yahr disability score of 2.0) were tested in the "on" state approximately 1.5 hours following the administration and fully responding to their PD medications. Subjects first initiated walking at self-initiated speeds to determine their cadences. Then, subjects were asked to initiate gait along the walkway while keeping pace with a metronome. The metronome rate (in beats/min) was set at a cadence 85% (slow condition), 100% (normal condition) and 115% (fast condition) of gait for each subject. Subjects were able to increase the speed of GI with faster cadence, but the speed of GI for the slow condition was similar to that of the normal condition. Swing toe-off was 578.3 ms for the fast condition, 709.4 ms for the normal condition and 736.2 ms for the slow condition. Respective times for swing heel-strike were 894.3 ms, 1110.2 ms and 1119.1 ms, and stance toe-off were 1105.4 ms, 1338.5 ms, and 1343.1 ms. Except for stance unloading ground reaction forces were greatest for the fast condition and smallest for the slow condition. It appears that PD patients were able to modulate GRFs and temporal events in response to auditory cues to achieve the peak acceleration force of the swing and stance limb. The findings from this study provided preliminary data, which could be used to investigate how PD patients modulate GRFs and temporal events during GI in response to tasks.

**Key Words:** Auditory cue; Gait initiation; Ground reaction forces; Parkinson's disease; Temporal events.

### Introduction

Patients with Parkinson's disease (PD) exhibit difficulty in performing transitional movement, such as during gait initiation (GI), termination, or turning (Bishhop et al, 2003; Dibble et al, 2004; Halliday et al, 1998; Martin et al, 2002; Morris et al, 2001). Difficulty in GI is one of the most common symptoms in PD patients and an important sign to be diagnosed as akinesia. Primary movement dysfunctions in PD patients include hypokinesia (reduced speed of movement), akinesia (absent movement or impaired initiation of movement), tremor, rigidity, and disturbed balance.

GI is defined as the transition from quiet stance to steady state gait. Muscles of the lower extremities are

activated stereotypically and create moments of force about the ankles and hip that rotate the body (Breniere and Do, 1986; 1991; Elble et al, 1994; Lepers and Breniere, 1995; Rogers and Pai, 1990). Initially, there is an inhibition of tonic soleus (SOL), which is active during quiet stance followed by the onset of tibialis anterior (TA) of both the swing and stance limbs. This combination is responsible for the backward movement of the center of pressure (COP) (Breniere and Do, 1986; Brunt et al, 1991; Crenna and Frigo, 1991). Swing limb hip abductors also create movement of the COP toward the swing limb (Rogers and Pai, 1990). Thus, muscle activity at the ankle and hip tends to propel the center of mass (COM) forward and toward the intended stance limb. Decoupling of

the COM and COP completes the first phase of gait initiation (Brunt et al, 1999; 2000; Jian et al, 1993). The second phase of GI is a stepping motion with a rapid increase in forward velocity of the center of mass, which is partly controlled by the stance limb TA followed by a burst of the stance SOL activity.

In PD patients, this initial phase is prolonged due to their inability to inhibit SOL together with inadequate recruitment of TA (Crenna et al, 1990). This prolonged phase was more than 1000 ms for PD patients compared to 600 ms for age matched healthy subjects. Because of the inability to inhibit SOL and recruit TA, the backwards movement of the COP was decreased (or absent in severe patients). The backwards movement of the COP is directly related to the initial forward acceleration of the center of mass (Breniere and Do, 1986). There is also decreased COP-COM magnitude in patients with PD compared to healthy elderly subjects during GI (Martin et al, 2002). Hass et al (2005) also recently demonstrated that more balance disabled PD patients have a significantly reduced peak magnitude of the COP-COM distance compared to the less disabled PD patients during the single limb support phase.

However, PD patients are able to improve how they initiate gait by either administration of levodopa or the presentation of an external cue (visual cues or auditory cues or cutaneous cues). An increase in swing limb loading, a decrease in the time to toe-off of the swing limb, and an increase in the forward velocity of the center of mass were reported with the use of cutaneous stimulation (Burleigh-Jacobs, 1997). Velocity, stride length, and cadence also have been improved with the aid of visual and auditory cues (Morris et al, 1994; Richards et al, 1992; Thaut et al, 1996). Clinically, PD patients are also able to improve their gait with the presentation of a visual cue such as a striped floor or an upturned walking stick (Dunne et al, 1987). Martin (1967) also reported improvements of stride length and gait velocity when PD patients walk over lines as visual cues perpendicular to a walkway.

Auditory cues in the form of a metronome or music beats or rhythmic clapping also improve gait velocity and cadence and reduce the number of freezing episodes in PD patients during turning (Enzensberger et al, 1997; McIntosh et al, 1997; Nanton, 1986; Quintyn and Cross, 1986; Thaut et al, 1996). In summary, sensory cues in various forms such as visual, auditory, and cutaneous stimulation aid gait in PD patients.

This form of intervention poses an interesting question. Are patients with PD now using visual or auditory cues to access the program to initiate gait thus by passing the need to 'self-initiate' movement, or are they using a new motor program for stepping, albeit still aided by a visual cue? Although various forms of sensory cues are used to improve gait in PD patients, the use of a metronome in the clinic recently got more attention because of being easy to use and carry, as well as being relatively inexpensive (Enzensberger et al, 1997). The studies on GI in PD are few and usually with a low sample size. No quantitative study has reported the effect of the three different levels of the auditory cue on GI in PD patients. The purpose of this study was to investigate the effects of auditory cues in the form of a metronome on GI in PD patients.

## Methods

### Subjects

2 patients (mean age: 54 yrs) with idiopathic PD participated in the study. All patients were tested in the "on" state approximately 1.5 hours following the administration and fully responding to their PD medications. All patients were Hoehn and Yahr (Hoehn and Yahr, 1967) disability score of 2.0. Each subject signed an informed consent form approved by the University Institutional Review Board prior to participation.

### Equipments

Two force platforms<sup>1)</sup>, embedded in a level walkway, were used to measure ground reaction forces of the stance and swing limb. Electrical foot switches<sup>2)</sup> were placed in the patients' shoes to measure heel-strike and toe-off of the swing limb and heel-off of the stance limb. Amplified force platform signals were sampled on-line at a rate of 1,000 Hz for 5 seconds<sup>3)</sup>. An electrical metronome was used as an auditory cue.

### Procedures

For each trial, subjects stood in a predetermined position with each foot on a force platform. Subjects first initiated walking at a self-initiated speed to determine their cadences. Then, subjects were asked to initiate gait along the walkway while keeping pace with a metronome<sup>4)</sup>. The metronome rate (in beats/min) was set at a cadence of 85% (slow condition), 100% (normal condition), and 115% (fast condition) of gait for each subject. The condition of these auditory cues was presented in random order.

### Data Analysis

Dependent measures include the slope and peak acceleration ground reaction forces (GRFs) of swing and stance limbs, loading of the swing limb (Fz), unloading of the stance limb (Fz), time to peak acceleration, swing heel-strike, and swing and stance toe-off. Timing data were determined and referenced to the first detectable onset of force platform activity. Mean and standard deviations (SD) were used to compare the different conditions.

## Results

### Temporal Events

Temporal events are shown in Figure 1 and Table 1. It appears that the auditory cue had an effect on

the speed of GI. As seen in Figure 1, the subjects were able to increase the speed of gait initiation with faster cadence of GI. Time to swing peak Fx was the shortest for the fast condition and longest for the slow condition. Swing toe-off was 578.3 ms for the fast condition, 709.4 ms for the normal condition, and 736.2 ms for the slow condition. Respective times for swing heel-strike were 894.3 ms, 1110.2 ms and 1119.1 ms and stance toe-off were 1105.4 ms, 1338.5 ms and 1343.1 ms.

### Ground Reaction Forces

Mean data is shown in Table 2. Generally, values were greatest for the fast condition and smallest for the slow condition, except for stance unloading. As seen in Table 2, swing to peak Fx, slope to swing peak, and stance Fx1 were greatest for the fast condition followed by the normal and slow condition. For the slow condition, both swing loading (Fz) and stance unloading (Fz) were similar for the slow condition, but the forces were not evenly distributed for the normal and the fast condition. However, stance peak Fz1 were similar among the different conditions.

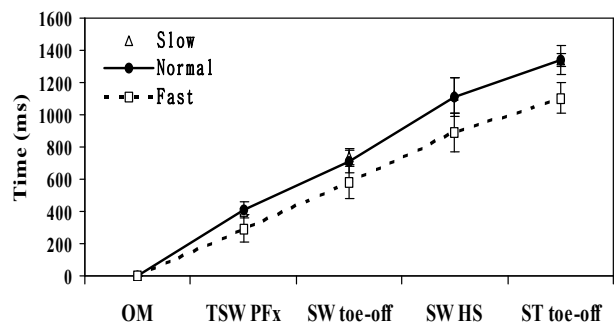


Figure 1. A comparison of temporal events on three different speeds of gait initiation (Slow, Normal, Fast). OM: onset of movement, TSW PFx: time to swing peak Fx, SW HS: swing heel-strike, ST: stance.

- 1) Advanced Mechanical Technology, Inc., Newton, MASS, U.S.A.
- 2) B & L Engineering, Los Angeles, CA, U.S.A.
- 3) BIOPAC Systems, Goleta, CA, U.S.A.
- 4) Yamaha QT1B, Yamaha Corp. of America, Buena Park, CA, U.S.A.

**Table 1.** The temporal events (ms)

Dependent variables	Slow	Normal	Fast
Time to swing peak Fx	404.1±19.7 <sup>a</sup>	406.3±49.6	295.1±83.4
Time to swing toe-off	736.2±49.8	709.4±67.5	578.3±99.6
Time to swing heel-strike	1119.1±111.9	1110.2±123.4	894.3±120.6
Stance time	1343.1±90.5	1338.5±40.4	1105.4±98.1

<sup>a</sup>Mean±SD.

**Table 2.** The for peak (%BW) and slope (%BW/s) for force plate

Dependent variables	Slow	Normal	Fast
Swing peak Fx	13.4±1.6 <sup>a</sup>	14.3±1.8	17.1±3.0
Slope to swing peak Fx	19.8±3.4	25.6±4.2	27.4±8.2
Stance peak Fx1	17.6±2.6	28.35±4.1	42.1±4.5
Swing Fz	54.5±4.7	62.3±5.1	62.9±7.0
Stance Fz	50.0±5.3	38.1±4.6	39.1±7.7
Stance Fz1	103.1±1.1	103.2±1.4	106.1±1.3

<sup>a</sup>Mean±SD.

## Discussion

This study examined the effects of auditory cues on the performance of GI in PD patients. The main finding was that PD patients were able to adequately modify their GRFs and timing events during GI to auditory stimuli provided by a metronome. GRF data indicated that there was an increase in the forces and the slope of the swing and stance Fx and Fz1 with the fast condition. Temporal events demonstrated that there was an improvement in swing toe-off, swing heel-strike, and stance to-off in PD patients for the fast speed condition compared to the slow and normal conditions. These findings are consistent with the results from previous studies which have found improvement in gait speed, cadence and stride length as a result of providing auditory cues in PD patients (McIntosh et al, 1997; Richards et al, 1992; Suteerawattananon et al, 2004; Thaut et al, 1996).

Previous studies (Brunt et al, 1999; Brunt et al, 2000) have shown that the acceleration forces (Fx) of the swing limb determine the intended velocity of GI. This acceleration force increases with faster speed or decreases when subjects reduce speed of

GI. PD patients increased the speed of GI for the fast condition. This increase was a result of the modulations of both the swing and the stance limb GRFs. This increase in force and slope was 19.6%, 3% and 7% respectively for swing Fx, stance Fz1 and slope to swing Fx when compared to the normal condition. PD patients also successfully reduced the speed of GI for the slow condition with the modulations of both the force and the slope. The force and slope were 6.6% and 22.6% decreased for swing Fx and stance Fz1 compared to the normal condition.

Swing toe-off for the fast condition that marks the initial phase of GI occurred approximately 22.6% slower than the normal condition. The acceleration force of stance Fx1 is related to the rate of swing toe-off. In the present study stance limb peak Fx1 for the fast condition was 48% increased compared to the normal condition. This increase in the stance peak Fx1 paralleled a decrease in the time to swing toe-off and, therefore, an increase in the speed of initiating movement. Either cadence or stride length or both can increase gait speed. PD patients appeared to increase the cadence of GI. Previous study (Suteerawattananona et al, 2004) observed an increase in the speed of gait induced by auditory cues

as a result of a faster gait cadence.

Swing limb heel-strike coincides with stance peak Fx2. A previous study (Brunt et al, 1999) has shown that stance peak Fx2 is related to walking speed. Thus, for fast speed time to stance peak Fx2 is reduced and stance peak Fx2 increases (Brunt et al, 1999). In the present study, subjects appear to increase the speed of the second phase of GI for the fast condition shortening swing time by 84.8 ms. Undoubtedly, the combination of these differences led to an increase in movement initiation speed for the fast condition. Stance toe-off was 233 ms earlier for the fast condition compared to the normal condition.

During the initial phase of GI the stance limb is unloaded so that the center of mass moves forwards and towards that limb by accelerating the forces. However, PD patients are impaired in distributing the forces of initial Fz GRF in both swing (loading) and stance (unloading) limb. In the present study, as seen in Table 2, both forces were not evenly distributed, except for in the slow condition.

### Conclusion

It appears that PD patients were able to modulate GRFs and temporal events in response to auditory cues to achieve the peak acceleration force of the swing and stance limb. Results from the current study suggest that PD patients may employ a different strategy by using alternative, directly controlled, brain circuitry to initiate with the use of a cue instead of using the defective internal rhythm from the basal ganglia (Azulay et al, 1996; Rubinstein et al, 2002). The findings from the current study provide preliminary data, which could be used to further investigate how PD patients modulate GRFs and temporal events during GI in response to tasks. In addition, the current research has not only provided us with new information concerning the stepping behaviors in PD patients, but has also shown that initiation from a position of

quiet stance is an important measurement tool for understanding the mechanisms of pathological gait patterns of motor behavior.

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