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Auditory cueing of gait initiation in Parkinson's disease patients with freezing of gait

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HIGHLIGHTS

- Parkinson's disease (PD) patients present failure to link anticipatory postural adjustments and step execution.
- Deficient postural adjustments in PD are associated with freezing of gait (FOG).
- Auditory cueing improves the preparation of gait initiation in PD patients with FOG but not its execution.

ABSTRACT

Objective: Impaired gait initiation (GI) in patients with advanced Parkinson's disease (PD) is a typical functional sign of akinesia. Failure to initiate the first step is frequently presented by patients with freezing of gait (FOG) and is often considered a sub-type of freezing. The literature on the effects of cueing of GI preparation and execution remains controversial. Our objective was to establish whether auditory cueing improves the preparation and/or execution of GI in PD patients with a history of FOG.
Methods: We recorded first-step preparation and execution in 30 PD patients with confirmed FOG under two randomised conditions: self-triggered (ST) gait and gait cued by a sound beep in off- and on-dopa conditions. Anticipatory postural adjustments (APAs) were evaluated by monitoring the trajectory of the centre of pressure.
Results: We compared the patients with 30 patients without history of FOG and 30 healthy controls (HCs). L-Dopa only slightly improved the characteristics of APAs in freezers but was effective to improve gait hypokinesia. Auditory cueing was effective in improving step preparation in freezers, who showed adequate APAs more frequently. As seen with HCs and patients without FOG, patients released their APAs more quickly when auditory cueing was applied. However, cueing did not have a significant effect on step length. Clinically, auditory cueing also improved start hesitation in freezers.
Conclusions: Auditory cueing improved step preparation but not step execution in PD patients.
Significance: A failure to link step preparation and execution during GI may explain the poor first-step execution seen in PD freezers.

1. Introduction

Impaired gait initiation (GI) in patients with Parkinson's disease (PD) is a typical functional sign of akinesia – a failure or slowness of willed movement (Hallett, 1990). According to Halliday et al. (1998), akinesia in PD can be defined as a difficulty in movement initiation (also known as 'freezing' – a brief episode during which patients find it impossible to generate effective, forward-stepping movements, in the absence of a cause other than parkinsonism or higher cortical impairments; Giladi and Nieuwboer, 2008; Mahabier et al., 2010). Freezing of gait (FOG) occurs in between 20% and 80% of PD patients, depending on the disease severity and duration. Although freezing can be sensitive to dopaminergic medications, it may become dopa-resistant and can even be induced by medication in some cases (Giladi et al., 2001; Giladi

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and Nieuwboer, 2008; Mahabier et al., 2010). In a study of 990 PD patients, Giladi et al. found that 318 had motor blocks and that 86% of the latter had blocks in GI (Giladi et al., 1992).

GI is accompanied by anticipatory postural adjustments (APAs). These APAs are essential because they allow unloading of the stepping leg and so create the conditions required for progression (Brenière and Do, 1991). Indeed, APA amplitude and duration are predictive of the subsequent gait velocity (Brenière and Do, 1991). During GI, healthy subjects always follow a highly stereotypical preparation pattern. Foot-off of the swing leg is preceded by co-activation of the tibialis anterior. This shift in body weight generates a displacement of the centre of pressure (COP) backwards and towards the swing leg. Next, a COP displacement towards the stance leg and then forwards is observed. Heel-off of the swing leg occurs at the start of the second phase of the COP displacement (i.e., a lateral shift towards the stance leg), with toe-off just before the forward COP displacement (Fig. 1) (Delval et al., 2005). Patients with PD show significant variability in the movement preparation time (Jacobs et al., 2009; Rogers et al., 2011) and a lower amplitude for the backward COP shift (Krystkowiak et al., 2006).

Failure of GI is a complex problem in advanced PD patients and the condition is almost completely unresponsive to treatment in patients with FOG. In fact, FOG is often resistant to dopaminergic therapy, with 90% of patients reporting no improvement with levodopa (Lamberti et al., 1997). Several attempts have been made to improve GI in PD. Dopaminergic medications or subthalamic nucleus deep brain stimulation (STN DBS) are effective means of improving GI in patients who do not present FOG (Elble et al., 1996; Liu et al., 2006; Rocchi et al., 2006; Crenna et al., 2006). However, STN DBS's effects on FOG remain controversial (Ferraye et al., 2008), since stimulation may increase the frequency of occurrence of FOG episodes.

Many studies have primarily focussed on the effect of rehabilitation strategies involving sensory cues on gait and falls in PD (with the largest trial in terms of number of subjects being the RESCUE study, Nieuwboer et al., 2007). However, evidence on retention is inconclusive. Moreover, assistive devices based on visual cues are not consistently beneficial in overcoming 'on' freezing in patients with PD (Kompoliti et al., 2000).

Four studies have focussed on the specific effect of external cues on GI in freezers. Cutaneous cueing reportedly improves the timing and movement outcome of GI in six PD subjects presenting FOG (Burleigh-Jacobs et al., 1997). The use of an external, cutaneous cue as a 'go' signal increased the force and velocity of APAs in both control subjects and PD subjects (regardless of whether the latter were on dopaminergic medication or not). In PD patients, the weak, delayed APAs for self-generated GI are improved by the administration of levodopa (Hiraoka et al., 2006). An auditory warning cue and a visual imperative cue were found to change the degree of soleus H-reflex depression during GI in eight PD patients with FOG and one without (Dibble et al., 2004). This finding suggests that external cues change the motor control of the ankle joint extensor muscles during GI in PD patients. However, a positive effect of external cueing was not fully confirmed by another study in seven PD patients complaining of FOG (Dibble et al., 2004). The authors also evaluated the impact of auditory and cutaneous sensory cueing on gait preparation (as evaluated by the COP trajectory and velocity) and execution (as evaluated by sacral and swing leg movements) in non-freezer patients and elderly and young adults. When the subjects were told to walk as fast as possible, both auditory and cutaneous cues produced an

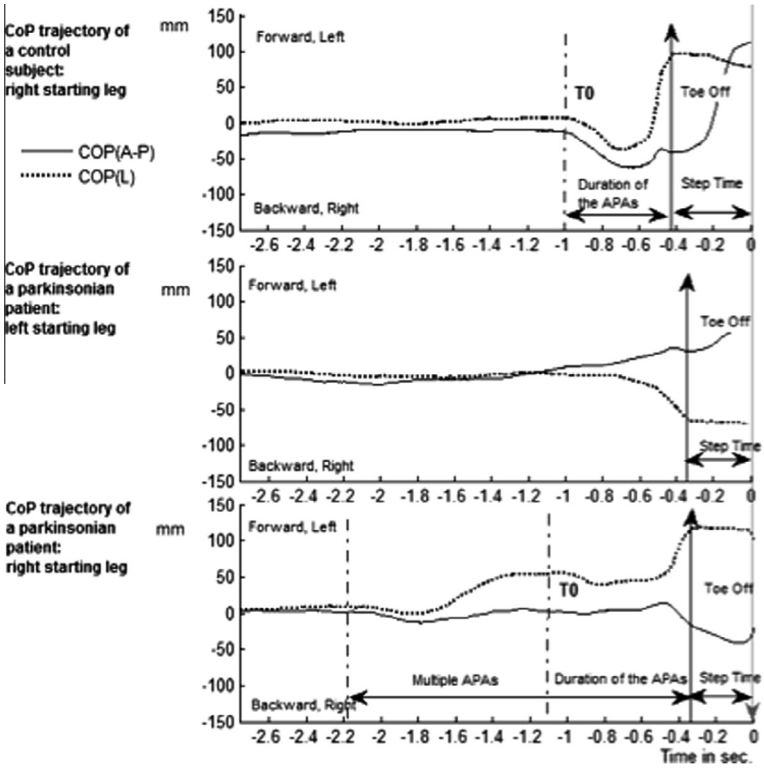

Fig. 1. Displacement of the centre of pressure (COP) until foot contact of the starting leg. T_0 was defined as the start of the anticipatory postural adjustment (APAs). It corresponded to the backward shift of the COP (COP(A-P)) and to the lateral shift of the COP(COP(L)) toward swing leg. TO corresponded to toe-off for the starting leg and was determined by tracking the trajectory of the toe marker in all three dimensions. The APA duration corresponds to the time interval between T_0 and TO. In the first case, COP trajectory was characterised by a backward and lateral shift toward right leg (starting leg) and then a lateral shift toward stance leg (left) before TO. This was considered as an anticipatory postural adjustment (APA). In the second case, COP trajectory was characterised by a forward and lateral shift toward stance leg. This was not considered as an appropriate APA. In the third case, The PD patient showed a series of APAs, with two separate sequences of lateral COP shift toward starting leg and backward shift. This was considered as multiple APAs.