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Bilateral coordination of gait and Parkinson’s disease: the effects of dual tasking

M Plotnik,1,2 N Giladi,1,3 J M Hausdorff1,4,5

ABSTRACT

The aetiology of gait disturbances in Parkinson’s disease (PD) is not fully understood. Recently, it was shown that in patients with PD, bilateral coordination of gait is impaired and that walking while being simultaneously engaged in a cognitive task is detrimental to their gait. To assess whether cognitive function influences the bilateral coordination of gait in PD, this study quantified left–right stepping coordination using a phase coordination index (PCI) that evaluates both the variability and inaccuracy of the left–right stepping phase (ϕ) generation (where the ideal ϕ value between left and right stepping is 180°). This report calculated PCI values from data obtained from force sensitive insoles embedded in subjects’ shoes during 2 min of walking in a group of patients with PD (n = 21) and in an age matched control group (n = 13). All subjects walked under two walking conditions: usual walking and dual tasking (DT) (ie, cognitive loading) condition. For patients with PD, PCI values were significantly higher (ie, poorer coordination) during the DT walking condition compared with usual walking (p < 0.001). In contrast, DT did not significantly affect the PCI of the healthy controls (p = 0.29). PCI changes caused by DT were significantly correlated with changes in gait variability but not with changes in gait asymmetry that resulted from the DT condition. These changes were also associated with performance on a test of executive function. The present findings suggest that in patients with PD, cognitive resources are used in order to maintain consistent and accurate alternations in left–right stepping.

Recent studies suggest that higher level cognitive function contributes to the control of gait, especially in patients with gait disturbances. This association is expressed by a slowed gait in normal adults when they walk and simultaneously perform an attention demanding task (ie, dual tasking (DT)). Further deterioration in gait parameters which reflect gait automaticity is seen in patients with Parkinson’s disease (PD) (eg, gait variability increases (gait rhythmicity decreases), as does gait asymmetry (GA) when patients performed a DT while walking). The effects of DT (eg, reduced gait rhythmicity) have been correlated with decreased executive function (EF). Further indicating that certain aspects of gait are under the influence of higher level cognitive function.

The present report focuses on the effects of DT on the bilateral coordination of gait, as manifested in the generation of left–right antephase stepping pattern in patients with PD. Under normal conditions, the left–right stepping phase difference fluctuates close to the “ideal” value of 180°. In previous work, we introduced a measure for quantifying the bilateral coordination of stepping. For each gait cycle, the relative phase difference of the stepping of one leg is defined with respect to the gait cycle (heel strike to heel strike) of the second leg. By combining the levels of accuracy and consistency of the phase generation, a phase coordination index (PCI) can be computed. Here, we tested whether PCI is influenced by DT in healthy older adults and in patients with PD.

METHODS

Subjects
We applied the PCI method to a data set described previously. Data from 21 patients with PD (15/6 men/women) and 13 healthy elderly subjects (6/7 men/women) were analysed. Mean ages were 71.9 (SD 7.3) and 68.4 (SD 4) years for the PD and control groups, respectively (p = 0.134). The study population was characterised with respect to age and cognitive function using the Mini-Mental State Examination, the motor part (III) of the Unified Parkinson’s Disease Rating Scale and the Hoehn and Yahr scale. Inclusion and exclusion criteria, as well as demographic and clinical characteristics, have been detailed previously. Briefly, none of the patients with PD suffered from motor response fluctuations or from freezing of gait (FOG), all were examined during the “ON” phase of the medication cycle and none suffered from dementia. The experimental protocols were approved by the Human Studies Committee of the Tel Aviv Sourasky Medical Centre. All subjects provided informed written consent according to the Declaration of Helsinki.

Gait protocol and analysis
Gait was examined under two conditions: (1) usual walking and (2) DT: the subject performed serial 7 subtractions (eg, 500, 493, 486). In both conditions the subjects walked, roughly in a straight line, for 2 min at a comfortable pace in a well-lit, obstacle free, 25 m long, 2 m wide corridor. Details on the paradigm and gait analysis system have been described previously. Briefly, temporal gait parameters (eg, swing time) were determined offline using force sensitive footswitches.

We focused on the analysis of the left–right stepping coordination using a recently developed quantitative measure that evaluates the phase, ϕ, between the step timing of the left and right legs. The measure is termed PCI. Lower PCI values reflect a more consistent and more accurate phase generation. Asymmetry in the motor symptoms of PD was assessed using a previously described measure.
Cognitive assessment
All participants also completed a computerised cognitive test battery designed to evaluate multiple cognitive domains. We measured EF using the Stroop and Go–NoGo tests (EF index), and memory (Memory index), which was used here as a control to see if any observed deficits were general or whether they were specific to EF.

Statistical analysis
To test the effect of DT on PCI, we first applied repeated measures analysis of variance (ANOVA, SPSS). Usual walking and DT walking are the two levels of within subjects effect, and “group” (PD and elderly) is the between subject effect. If a significant group × condition interaction was observed, post hoc analysis (paired t test) was used to study the effect of walking condition within each group separately. Correlations were inspected by using Spearman’s correlation analysis. A p value less than or equal to 0.05 was considered statistically significant.

RESULTS
As previously observed, in both groups, DT significantly reduced gait speed. For the PD group, mean values for gait speed were 1.05 (SE 0.05) m/s during usual walking and 0.85 (0.06) m/s during the DT condition (p < 0.001; ~20% reduction). The corresponding values for the control group were 1.37 (0.04) m/s and 1.22 (0.05) m/s, respectively (p < 0.001; ~12% reduction).

Bilateral coordination of gait, as expressed by the PCI, was affected by DT (ANOVA, p = 0.001) with a significant group × condition interaction (p = 0.014). PCI was affected by DT in patients with PD (p < 0.001, paired t test) but not significantly in healthy controls (p = 0.290) (fig 1). No correlation was found between PCI values in both walking conditions and the level of asymmetry in the motor symptoms of PD (Spearman’s p < 0.17, p > 0.46).

<table>
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<th>Table 1 Association between the change in phase coordination index (PCI) and changes in other measures of gait*</th>
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<td><strong>Healthy subjects</strong></td>
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Entries are Spearman’s p (p-values).

*Relative changes are defined as the ratio between the value in the dual task condition and the value in the usual walking condition. Significant correlations are in bold type.
PCI differences between the groups were statistically significant during both walking conditions (ANOVA, p = 0.005). During usual walking, mean values for PCI were 5.24 (SE 0.61)% and 3.24 (0.18)% for the PD and control groups, respectively (t test, p = 0.017). During the DT condition, mean values for PCI were 7.71 (SE 0.91)% and 3.67 (0.38)% for the PD and control groups, respectively (t test, p = 0.002).

In the control group, the change in PCI was not significantly associated with the change in gait variability or in GA (marginally significant association was observed between the change in PCI and the change in swing time variability). In contrast, in the PD group, the change in PCI was significantly associated with the changes in gait variability (table 1).

Among patients with PD, the relative change in PCI due to the DT condition was not significantly correlated with the Memory Index (Spearman’s ρ = 0.17; p = 0.475) and was marginally significantly inversely correlated with the EF Index (Spearman’s ρ = −0.43; p = 0.055). Closer inspection revealed that this association was largely driven by performance on the Stroop Test; the association between this change in PCI and Stroop Test scores was significant (Spearman’s ρ = −0.47; p = 0.043). The inverse relationship indicates that patients who performed better on this test of EF displayed less deterioration in bilateral coordination of gait during DT (see Yogev et al for further details).

DISCUSSION
We found that bilateral coordination of gait (as measured by the PCI) was impaired during the DT condition compared with baseline conditions in PD but not in healthy elderly subjects. EF apparently contributes to the change in the PCI in response to DT in patients with PD. These results confirm earlier findings that have shown that gait rhythmicity and GA may be influenced by attention loading in patients with PD.

According to the capacity sharing theory, when two functions that use the same resources are performed simultaneously, the performance of one or both of these functions may be compromised. Empirical data suggest that different aspects of gait may be affected in different cohorts in response to DT conditions. In the present study, for example, gait speed was reduced in both groups but PCI was increased significantly only in the PD group.

Increased gait variability and asymmetry were also observed in older “fallers”, consistent with the high prevalence of falls among patients with PD. Thus we suggest that these two patient populations employ cognitive resources in order to maintain regular walking, and once cognitive resources are diverted from gait (eg, an attention shift), the overall gait may be affected in different cohorts in response to DT.

Intriguingly, in patients with PD, in the context of another diverted from gait (eg, an attention shift), the overall gait may be affected in different cohorts in response to DT walking is most likely different than the one underlying the increase in GA, a point which warrants further investigation.

We speculate that gait and DT intensifies the demands on the neuronal computational resources which are carried out in the brain’s frontal lobe, a brain area which was already shown to be involved in the coordination of bimanual movements, including gait on the one hand and in the performance of EF and attention management on the other. The former capacity is related to the supplementary motor area, and the latter, in part, to the dorsolateral prefrontal cortex. Both of these frontal areas receive neuronal input from the basal ganglia, which are impaired in PD. Therefore, we suggest that the volatile mixture of competition for limited computational resources (ie, neuronal circuits involving the frontal lobe) and impaired input to these brain regions are expressed in poor bilateral coordination of gait in PD.

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Competing interests: None.

Ethics approval: The experimental protocols were approved by the Human Studies Committee of the Tel Aviv Sourasky Medical Centre.

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