Overestimation of stability limits leads to a high frequency of falls in patients with Parkinson’s disease

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Objectives: To test a hypothesis that patients with Parkinson’s disease may not notice discrepancies between their perceived and actual stability limits and cannot keep their centre of gravity within the stability region.

Settings: Outpatients with neurological disorders in rehabilitation service.

Subjects: Twenty-one patients with Parkinson’s disease (11 men, 10 women; mean duration 5.9 ± 3.9 years) and age- and sex-matched healthy volunteers were recruited.

Methods: Each subject’s right arm length was subtracted from the distance between the right acromion and the perceived reachable boundary. This was called ‘perceived reach’. The figure given by subtracting the right arm length from the maximum forward reach length measured by the Functional Reach Test was named ‘actual reach’, and is an index of actual stability limits in each subject. The difference between actual and perceived stability limits (DAP) is given by actual reach minus perceived reach. The motor score of the Unified Parkinson’s Disease Rating Scale were used to evaluate disease severity.

Results: The mean DAP for the Parkinson’s disease group was negative (−1.8 ± 5.7 cm) and significantly different from that of controls (3.3 ± 9.2 cm) (P < 0.05). In Parkinson’s disease, DAP was significantly correlated with the Unified Parkinson’s Disease Rating Scale score (correlation coefficient = −0.39, P < 0.05).

Conclusions: These results indicated that patients with Parkinson’s disease overestimated their stability limits, which may result in falls. In addition, the results demonstrate that patients with Parkinson’s disease develop overestimation of stability limits in parallel with their disease progression.

Introduction

The ability to perform intentional movements of the centre of gravity when leaning or carrying out weight-shifting activities is critical to the successful performance of various functional tasks associated with activities of daily living. To evaluate the ability to perform intentional movements of the centre of gravity, stability limits have generally been used. To keep the centre of gravity within the stability region, we must stay within stability limits and perceive precise stability limits before movements. Two technical terms need to
be defined: ‘perceived stability limits’ are stability limits that one perceives before movement and ‘actual stability limits’ are stability limits that are actually measured. Under normal conditions, perceived stability limits are consistent with actual stability limits. However, we hypothesized that in pathological conditions there may be a discrepancy between perceived and actual stability limits and this discrepancy may cause falls.

Tests designed to evaluate actual stability limits, such as the Functional Reach Test, are commonly applied in reaching tasks while perceived stability limits have received little attention. In addition, none of those studies evaluated patients with disease. Parkinson’s disease is characterized by bradykinesia, tremor or postural instability, but patients with Parkinson’s disease also experience difficulties in keeping balance and are often reported to fall when performing activities of daily living that require dynamic postural control. Actual stability limits in Parkinson’s disease patients are narrow, but we cannot find any reports describing a discrepancy between perceived and actual stability limits in such patients.

We hypothesize that patients with Parkinson’s disease tend to overestimate their stability limits compared with age-matched healthy elderly people, and this overestimation is a risk factor for falls. The purpose of this study is to test our hypothesis.

**Methods**

Twenty-one patients with Parkinson’s disease (11 men; 10 women) were recruited from the outpatients department at Osaka University Hospital, and 21 age- and sex-matched healthy elderly volunteers were also recruited as a control group. All subjects had no obvious visual deficit, could walk for 10 m and stand independently without aids. The duration from disease onset was 5.9 ± 3.9 years (range 1–16). Patients scored more than 24 on the Mini-Mental State Examination and were diagnosed not to be demented.

All subjects gave informed consent for the protocol, which was in accordance with the Declaration of Helsinki and ethically assessed and approved by the Human Studies Committee of Osaka University Graduate School of Medicine.

Height and right arm length, defined as the distance from the acromion to the distal end of metacarpal bone, for each participant was measured. The Hoehn and Yahr Disability Scale and motor score of the Unified Parkinson’s Disease Rating Scale were scored in each patient with Parkinson’s disease to evaluate disease severity.

The subject was asked to stand with the feet shoulder-width apart and the right shoulder 5 cm from the wall. A centimeter-based yardstick was mounted horizontally on the wall at the height of the right acromion and a target was put on the yardstick. The target was 20 cm in length and 1 cm in diameter, with a red marker at its tip. The subject was asked to look at the marker of the target with arms at his or her sides. The examiner moved the target away from the subject and, when the subject judged that the target had arrived at the reachable boundary, recorded the distance between the acromion and the boundary (Figure 1a). The distance between right acromion and the reachable boundary minus the subject’s right arm length was defined as an index of perceived stability limits, called ‘perceived reach’ (Figure 1b).

The actual stability limit was measured using the Functional Reach Test according to the method by Duncan et al. Subtraction of the right arm length from the maximum forward reach length measured by the Functional Reach Test was named ‘actual reach’, and is an index of actual stability limits in each subject (Figure 1c). Finally, we subtracted perceived reach from actual reach to give an index of difference between actual and perceived stability limits (DAP).

Independent sample t-tests were used to assess the difference of the mean values in each variable (age, height, arm length, actual reach, perceived reach and DAP) between the Parkinson’s disease group and the control group. To assess the difference between actual

![Figure 1](image-url)
reached and perceived reach in the Parkinson’s disease subjects. Dependent sample t-tests were used. Furthermore, in the Parkinson’s disease group we used correlation analysis between DAP and the other variables (age, disease duration, height, arm length, actual reach, perceived reach, and Unified Parkinson’s Disease Rating Scale score). In all statistical analyses, we used statistical computer software, SPSS version 2. Statistical significance was defined as $P < 0.05$.

Results

The characteristics of the Parkinson’s disease and control groups are shown in Table 1. There are no significant differences between two groups concerning age, height, and arm length.

The severity of parkinsonism ranged from stage 1 to stage 4 (2 patients in stage 1, 11 patients in stage 2, 4 patients in stage 3, and 4 patients in stage 4) on the Hoehn and Yahr scale, and the mean ± standard deviation (SD) Unified Parkinson’s Disease Rating Scale motor score was 23.4 ± 10.7 (range 6–42).

In the Parkinson’s disease group, the mean perceived reach (26.1 ± 7.6 cm) was not significantly longer than that of actual reach (24.3 ± 5.7 cm), but the mean DAP (1.8 ± 5.7 cm) was negative, and significantly different from that of the control group (3.3 ± 9.2 cm) ($P < 0.05$). These results indicated that patients in the Parkinson’s disease group overestimated their stability limits more than controls.

In the Parkinson’s disease group, the DAP was significantly correlated with Unified Parkinson’s Disease Rating Scale score (correlation coefficient = −0.39, $P < 0.05$) (Figure 2) and with perceived reach (correlation coefficient = −0.67, $P < 0.01$).

Discussion

Our results indicated that patients with Parkinson’s disease tended to overestimate their stability limits more than controls. Robinovitch found that healthy young subjects tended to underestimate their reaching abilities, and they hypothesized that this underestimation was a potential safety factor to reduce the risk of losing their balance. Overestimation in Parkinson’s disease may suggest that patients with Parkinson’s disease lose this potential safety factor and have a tendency to plan movements outside their capabilities, with the risk of losing their balance. Patients with Parkinson’s disease have difficulty in correcting their posture when their centre of mass exceed stability limits, have discoordinated postural movement patterns and experience dysequilibrium in preparing a new base of support. In addition to these balance disorders, overestimation of stability limits may promote falling in such patients. Thus, we considered that it might be useful to confirm and improve their estimation of stability limits to prevent them from accidental falling.

In the Parkinson’s disease group, there was a significant negative correlation between DAP and Unified Parkinson’s Disease Rating Scale score. This indicates significant correlation between severity of parkinsonism and overestimation of stability limits. In addition, the DAP of Parkinson’s disease showed a significant negative correlation with perceived reach. Robinovitch hypothesized that estimation errors from the narrowness of actual stability limits correlate with reaching ability. However, in our study we demonstrated also that overestimation of stability limits resulted from disturbed perception of stability limits in patients with Parkinson’s disease. Since our patients were not demented, this disturbed perception was not correlated with cognitive dysfunction. We supposed this disturbance might be a result of disturbed spatial ability.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Characteristics of the Parkinson’s disease and control groups</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>Parkinson’s disease group</td>
</tr>
<tr>
<td></td>
<td>65.4 ± 6.6</td>
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<tr>
<td>Height (cm)</td>
<td>158.4 ± 6.9</td>
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<tr>
<td>Arm length (cm)</td>
<td>56.8 ± 3.7</td>
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<tr>
<td>Actual reach (cm)</td>
<td>24.3 ± 5.7</td>
</tr>
<tr>
<td>Perceived reach (cm)</td>
<td>26.1 ± 7.6</td>
</tr>
<tr>
<td>DAP (cm)</td>
<td>−1.8 ± 5.7</td>
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NS, not significant; DAP, difference between perceived and actual stability limits.
Our study demonstrates that patients with Parkinson’s disease develop overestimated stability limits in parallel with their disease progression. And this overestimation of stability limits may be a key risk factor for falling. The weakness of our study was in the limited numbers of patients and controls. Thus, a further study to correlate severity of overestimation and falling may be needed to develop new rehabilitation methods for fall prevention in patients with Parkinson’s disease.

Clinical messages

- Patients with Parkinson’s disease overestimate stability limits and tend to make movements that result in loss of balance and falls.
- Rehabilitation to perceive stability limits correctly is needed to reduce the risk of falls in patients with Parkinson’s disease.

References

Overestimation of stability in Parkinson’s disease


