

The influence of visual control on postural stability in Parkinson disease

Wpływ kontroli wzrokowej na stabilność posturalną w chorobie Parkinsona

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Neurologia i Neurochirurgia Polska 2011; 45, 2: 132–139

Abstract

Background and purpose: The aim of the study was to evaluate the influence of visual control on parameters of postural stability among patients with Parkinson disease (PD) in comparison with control subjects.

Material and methods: Fifty patients diagnosed with idiopathic PD and 50 control subjects without features of central nervous system injury were selected for the study. The clinical diagnosis of idiopathic PD was established according to the clinical criteria of the United Kingdom Parkinson's Disease Society Brain Bank. Only patients in stages I–III according to the Hoehn-Yahr scale were included. The range of sway of the centre of foot pressure (COP) in the frontal plane (COP_x) and in the sagittal plane (COP_y), as well as the total path length in both axes (COP_{xy}), was tested during quiet standing with and without visual control.

Results: COP_{xy} with and without visual control was the smallest in the group of patients in stage II in comparison with patients in stage I and III according to Hoehn-Yahr and in comparison with the control group.

Conclusions: Visual control significantly affects the parameters of postural stability in PD patients.

Key words: Parkinson disease, postural stability, posturography.

Streszczenie

Wstęp i cel pracy: Zaburzenia stabilności postawy są istotnym elementem obrazu klinicznego choroby Parkinsona (ChP). Celem pracy była ocena wpływu kontroli wzrokowej na parametry stabilności posturalnej wśród chorych na idiopatyczną ChP w porównaniu z osobami bez objawów uszkodzenia ośrodkowego układu nerwowego (OUN).

Materiał i metody: Badaniem objęto 50 chorych na idiopatyczną ChP oraz 50 osób bez cech uszkodzenia OUN stanowiących grupę kontrolną. Kliniczne rozpoznanie idiopatycznej ChP ustalono na podstawie obowiązujących kryteriów *United Kingdom Parkinson's Disease Society Brain Bank*. Do badania zakwalifikowano chorych w stadiach I–III choroby wg skali Hoehn i Yahra. Oceniano zakres przemieszczeń środka nacisku stóp (COP) w płaszczyźnie czołowej (COP_x), w płaszczyźnie strzałkowej (COP_y) oraz całkowitą długość drogi środka nacisku stóp (COP_{xy}) podczas swobodnego stania z kontrolą wzrokową lub bez takiej kontroli.

Wyniki: COP_{xy}, zarówno pod kontrolą wzroku, jak i bez kontroli wzroku, była najmniejsza w grupie osób w stadium II wg Hoehn i Yahra w porównaniu z osobami w stadium I i III wg Hoehn i Yahra oraz w porównaniu z grupą kontrolną.

Wnioski: Kontrola wzrokowa ma istotny wpływ na parametry stabilności posturalnej w grupie chorych na ChP.

Słowa kluczowe: choroba Parkinsona, stabilność posturalna, posturografia.

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Received: 6.01.2010; accepted: 2.12.2010

Introduction

Parkinson disease (PD) is a chronic disorder of the central nervous system (CNS) that progressively impairs functioning of the affected persons. Disorders of posture and balance in PD are an important element of the clinical picture. They negatively affect patients' quality of life. Balance is defined as a state of vertical orientation of the body enabled by the reciprocal correlation of the forces and their moments. It is provided by the reflex tone of the postural (anti-gravitational) muscles with the involvement of the nervous system [1,2].

Postural disturbances are usually non-specific [3,4]. Patients with disorders of similar aetiology may have completely unrelated postural disturbances. Conversely, patients with distinct disorders might experience similar postural disturbances.

Postural instability in PD is one of the major factors leading to the increased risk of falls and related complications [1,5,6]. The search for the possibility of early identification of PD patients with increased risk of falls is therefore important. Given the paucity of studies suggesting the importance of visual control in the maintenance of postural stability, a study in this area was designed.

Available evidence suggests that permanent or episodic balance disturbances in subjects older than 65 occur in more than 50% of PD patients [7-9]. The studies performed to date show that more advanced age and increased burden of CNS lesions lead to postural instability that may result in falls. Marchese, Horak, and Beckley found no difference in range of sway between PD patients and elderly healthy subjects in tests performed with eyes open or closed. Lack of visual control led to worsening of postural stability in both groups [10-12].

Discrepancies among available studies suggest that changes in the range of sway in two planes are not an intrinsic feature of PD [13]. Błaszczyk *et al.* showed that the severity of pathological signs in PD and limitation of visual control significantly affected the ability to maintain normal stability of body posture – range of sway in patients was greater than in controls both with and without visual control [14].

The aim of the study was to evaluate the influence of visual control on parameters of postural stability among patients with idiopathic PD in comparison with control subjects.

Material and methods

The study was performed in the One-Day Diagnostics and Treatment Facility within the Advanced Age Neurology Department and in the Outpatient Clinic of that department between 2007 and 2008. The study group comprised 50 patients with idiopathic PD. The control group consisted of 50 subjects without any signs of CNS injury. Both the study and control group were similar regarding age, height and body weight.

Other demographic and clinical characteristics of both groups divided additionally by sex are provided in Table 1.

Clinical diagnosis of idiopathic PD was established in each case using the United Kingdom Parkinson's Disease Society Brain Bank criteria [15] by neurologists with expertise in diagnostics and treatment of movement disorders.

Stage of the disease was assessed with the score in part III of the Unified Parkinson's Disease Rating Scale (UPDRS) and according to the Hoehn & Yahr (H&Y) grading scale [16]. In each case, the comprehensive medical history was obtained, including the onset, duration of the disease, treatment and concomitant disorders. Patients were divided into three subgroups according to the grading in the H&Y scale (Table 1).

Postural stability was evaluated with a tensometric force platform (AccuGait, AMTI) measuring the forces (F_x , F_y , F_z) and force moments (M_x , M_y , M_z) exerted by the subject's feet during testing. Diagnostic tests were performed during quiet standing with eyes open and with eyes closed. A single test took 30 seconds, and frequency of sampling was 50 Hz. During the first trial, the subject stood still with his/her arms along the trunk and with the eyes open. The second trial involved the removal of visual information (the subject closed his/her eyes). The interval between two trials was no longer than 10 seconds. Participants did not leave the platform between trials. During the testing, subjects were informed about the beginning and the end of the trial.

The postural stability in both groups was evaluated with three variables: (1) the range of the centre of foot pressure (COP) sway in the frontal plane (COP_x); (2) the range of the COP sway in the sagittal plane (COP_y); and (3) the total path length of COP in both axes (COP_{xy}).

Inclusion criteria for the study group consisted of: (1) diagnosis of idiopathic PD; (2) age \geq 40 years;

Table 1. Demographic and clinical data in subgroups divided according to gender

	Hoehn & Yahr stage I (subgroup I)	Hoehn & Yahr stage II (subgroup II)	Hoehn & Yahr stage III (subgroup III)	Study group	Control group
Number of patients					
females	6	7	7	20	20
males	4	13	13	30	30
Age [years]					
females	58 ± 8.7	62.5 ± 9.8	78.8 ± 9.7	62.9 ± 9.7	58.1 ± 8.2
males	56.4 ± 10.2	64.6 ± 7.7	68 ± 10.0	65.1 ± 9.5	66.9 ± 9.6
Weight [kg]					
females	78.5 ± 15.3	73.2 ± 11.2	71.1 ± 15.1	74.1 ± 13.5	76.1 ± 13.2
males	81 ± 12.2	76.7 ± 7.7	77.9 ± 13.9	77.8 ± 11.0	77.1 ± 14.1
Height [cm]					
females	164.5 ± 4.18	167.4 ± 6.7	170.1 ± 5.8	167.5 ± 5.9	170.7 ± 9.3
males	172.2 ± 6.2	168.8 ± 9	171.7 ± 9.7	170.5 ± 8.9	171.6 ± 7.3
Disease duration [years]					
females	3.5 ± 1.3	8.2 ± 1.1	14.8 ± 3.2	9.1 ± 5.1	
males	3.5 ± 1.4	9.07 ± 4.3	12.5 ± 3.0	9.9 ± 4.4	
UPDRS ('on' state) [pts]					
females	11.6 ± 2.0	21.2 ± 3.6	24.8 ± 4.9	19.6 ± 6.6	
males	11 ± 1.1	18.4 ± 4.7	26.8 ± 4.5	21.1 ± 7.0	

UPDRS – Unified Parkinson's Disease Rating Scale. All differences between patients and controls were non-significant.

(3) stage I–III on H&Y scale; (4) treatment with levodopa or dopamine agonist.

Results were statistically analysed with the Mann-Whitney *U*-test. Differences between groups in variables that described posture were analysed with ANOVA for repeated measures including the group effect (4) and visual control effect (2) (4×2). Post-hoc analysis with the NIR test was used to establish the difference between particular tests in groups. All analyses were performed with the 'STATISTICA' statistical package.

Results

COPx

Mean COPx with visual control in PD patients in H&Y stage I was 16.4 ± 8.7 mm, and the corresponding value in PD patients in H&Y stage III was 17.9 ± 10.8 mm. Mean COPx with visual control in studied PD patients in H&Y stage II was 11.7 ± 5.8 mm, and mean COPx with visual control in controls was 12.8 ± 6.8 mm.

Mean COPx without visual control in PD patients in H&Y stage I was 24.8 ± 14.4 mm, and the corre-

sponding value in PD patients in H&Y stage III was 32.1 ± 17.7 mm. Mean COPx without visual control in studied PD patients in H&Y stage II was 21.6 ± 5.8 mm, and mean COPx with visual control in controls was 21.7 ± 11.6 mm.

Two-factorial ANOVA 4×2 (group \times visual control) showed a significant influence of both factors on the measurement results [group effect $F(3,89) = 3.7$; $p < 0.014$; visual control effect, $F(3,89) = 59.2$; $p < 0.001$].

Post-hoc analysis of NIR type (results provided in Table 2) showed that the mean range of sway in the frontal plane without visual control differed significantly between patients in H&Y stage II and III of the disease ($p < 0.003$) and between patients in H&Y stage III of the disease and controls ($p < 0.001$).

COPY

Mean COPY with visual control in controls was 19.7 ± 8.2 mm. The same measure in PD patients in H&Y stage I was 24.3 ± 11.2 mm. Mean COPY without sight control in PD patients in H&Y stage II was smaller than in controls (28.5 ± 8.3 mm and 30.3 ± 10.8 mm, respectively). Removal of sight

control increased COP_y in PD patients in H&Y stage I and III (35.2 ± 12.8 mm and 35.0 ± 20.0 mm, respectively).

ANOVA adjusted to the sex of the studied subjects showed a significant influence of visual control effect [F(3,89) = 29.78.2; *p* < 0.001] on the measurement results, while the group effect was insignificant [F(3,89) = 2.85; *p* < 0.41].

Post-hoc NIR analysis did not show any difference among studied groups (Table 3).

COP_{xy}

Mean COP_{xy} with visual control in PD patients in H&Y stage I was 415.9 ± 80.7 mm, and the corresponding value in PD patients in H&Y stage III was 515 ± 200.8 mm. Mean COP_{xy} with visual control in studied PD patients in H&Y stage II was 384.9 ± 42.8 mm, and mean COP_{xy} with visual control in controls was 399.6 ± 90.5 mm.

Mean COP_{xy} without visual control differed significantly between patients in H&Y stage I (547.7 ± 107.4 mm) and H&Y stage III (687.6 ± 243.7 mm) (*p* < 0.007), between PD patients in H&Y stage II (500.5 ± 109.9 mm) and H&Y stage III (*p* < 0.00004), and between PD patients in H&Y stage III and controls (526.2 ± 129.9 mm) (*p* < 0.00002) (Table 4).

COP_{xy} in PD patients in H&Y stage II was shorter than in controls, both with and without visual control.

Results in men and women were combined and two-factorial ANOVA 4 × 2 (group × visual control) showed a significant influence of both factors [group effect, F(3,89) = 9.94; *p* < 0.00001; visual control effect, F(3,89) = 41.003; *p* < 0.001] on the measurement results.

Post-hoc analysis of NIR type showed that the mean COP_{xy} without visual control differed significantly between patients in H&Y stage II and III of the disease (*p* < 0.004) and between patients in H&Y stage III of the disease and controls (*p* < 0.002), when tested with visual control.

Discussion

The essence of the study was the categorization of PD patients according to the disease stages, as proposed by Hoehn and Yahr. It enables more accurate testing of mechanisms related to postural instability in the

Table 2. Results of NIR post-hoc statistical analyses for the range of sway in the frontal plane

Group	H&Y stage I Eyes open	H&Y stage I Eyes closed	H&Y stage II Eyes open	H&Y stage II Eyes closed	H&Y stage III Eyes open	H&Y stage III Eyes closed	Control group Eyes open	Control group Eyes closed
H&Y stage I, Eyes open		0.0148	0.2523	0.1917	0.6988	0.0002	0.3158	0.1326
H&Y stage I, Eyes closed			0.0014	0.4296	0.0926	0.0772	0.0008	0.3742
H&Y stage II, Eyes open				0.0003	0.0832	0.0000	0.7114	0.0008
H&Y stage II, Eyes closed					0.2998	0.0039	0.0029	0.9867
H&Y stage III, Eyes open						0.0000	0.0873	0.2098
H&Y stage III, Eyes closed							0.0000	0.0006
Control group, Eyes open								0.0000
Control group, Eyes closed								

H&Y – Hoehn & Yahr

Table 3. Results of NIR post-hoc statistical analyses for the range of sway in the sagittal plane

Group	H&Y stage I Eyes open	H&Y stage I Eyes closed	H&Y stage II Eyes open	H&Y stage II Eyes closed	H&Y stage III Eyes open	H&Y stage III Eyes closed	Control group Eyes open	Control group Eyes closed
H&Y stage I, Eyes open	0.0114	0.4848	0.3311	0.0810	0.4548	0.0143	0.2141	0.1106
H&Y stage I, Eyes closed	0.0015	0.1211	0.0315	0.1009	0.0859	0.0295	0.0000	0.1989
H&Y stage II, Eyes open							0.5898	0.0042
H&Y stage II, Eyes closed							0.0049	0.5543
H&Y stage III, Eyes open							0.0134	0.3834
H&Y stage III, Eyes closed							0.0000	0.1396
Control group, Eyes open								0.0000
Control group, Eyes closed								0.0000

H&Y – Hoehn & Yahr

Table 4. Results of NIR post-hoc analyses for the total path

Group	H&Y stage I Eyes open	H&Y stage I Eyes closed	H&Y stage II Eyes open	H&Y stage II Eyes closed	H&Y stage III Eyes open	H&Y stage III Eyes closed	Control group Eyes open	Control group Eyes closed
H&Y stage I, Eyes open	0.0167	0.5434	0.0973	0.0550	0.0550	0	0.7148	0.0139
H&Y stage I, Eyes closed	0.0016	0.3539	0.0076	0.5255	0.0070	0.0070	0.0010	0.6294
H&Y stage II, Eyes open							0.6909	0.0001
H&Y stage II, Eyes closed							0.0067	0.4853
H&Y stage III, Eyes open							0.0024	0.7664
H&Y stage III, Eyes closed							0	0.0000
Control group, Eyes open								0.0000
Control group, Eyes closed								0.0000

H&Y – Hoehn & Yahr

discussed group of patients. Assessment of the early, initial stage of the disease and the search for potential disturbance of stability was related not only to controls but also to the patients in consecutive stages of the disease. Evolution of particular signs is divergent and balance disturbances occur only in H&Y stage III. That is why patients in stage I and II were also assessed.

Our results are partially concordant with the previous studies. The results of posturographic studies in PD patients published to date are equivocal in terms of the range of sway in frontal and sagittal planes [13].

Błaszczuk *et al.* found that patients older than 65 lacked appropriate motor coordination [17]. Studies in PD patients revealed an association between falls and duration of the disease, its stage on the H&Y scale, and the daily levodopa dose. Analysis of falls in relation to the time showed that 8 out of 25 studied patients fell down because of postural instability [18].

Results of other studies confirm that the deficit of postural stability increases with age and provides the opportunity to measure changes in range and control of the displacement of the centre of gravity. Restoration of balance depends primarily on adequacy of the balance control system, on parameters of the destabilizing stimulus, and on compensatory mechanisms [19].

Compensatory mechanisms in PD patients include a shift of the location of the centre of gravity projection. This projection is markedly shifted towards the side of the body which is unaffected or less affected [20]. Patients in H&Y stage II present with bilateral signs of the disease without disordered balance and their range of sway in both frontal and sagittal planes is smaller. Their centre of gravity varies in relation to the increased foot-support area.

Analysis of sway suggests that the described compensatory mechanism is best developed in patients in H&Y stage II, and therefore their range of sway in the frontal and sagittal plane, both with and without visual control, is similar to that seen in controls.

We tested the difference in sway in COP during quiet standing with and without visual control. Sway in the sagittal plane in PD patients in H&Y stage I with visual control was greater by 3.0 mm than in H&Y stage II patients, and the results of the latter group differed from controls by 1.6 mm. Sway during testing without visual control was smaller by 1.8 mm in H&Y stage II patients than in controls. These differences were insignificant.

Winter observed a lack of difference in the range of sway between two groups in the sagittal plane only.

This result may be related to the independent control of range of sway in the frontal and sagittal plane. Lack of information from one sensory modality – vision – was a very important factor increasing the sway of posture. In other groups of PD patients, increase of sway in COPy was much greater than in controls [6].

Orawiec studied 13 PD patients without further categorization according to the H&Y scale and found that the difference in sway in the sagittal plane between patients and controls was 8.2 mm with sight control and 8.8 mm without sight control [21]. Post-hoc NIR analysis confirmed significant differences between analysed groups during testing with and without visual control. The group factor and sight factor were both significant [21].

Błaszczuk *et al.* found a difference of 104 mm between patients and controls in sway with visual control (160.8 mm without visual control). Effects of group and sight were significant. Post-hoc NIR analysis also revealed significant differences between studied groups [14].

The sway should be the smallest in our study in PD patients in H&Y stage I because of mild unilateral signs and short duration of the disease. Sway in the frontal plane did not follow that expectation. Actually, the sway in PD patients in stage II according to H&Y was the smallest in comparison with other groups and was comparable with controls.

The results obtained in the frontal plane with the eyes closed were also similar in PD patients in H&Y stage II and in controls. Sway was markedly increased among studied patients when visual control was removed. Lack of visual control during quiet standing caused an increase in sway in all groups. The greatest sway in the frontal plane was recorded in PD patients in H&Y stage III, and corresponding values in the sagittal plane were noted in PD patients in H&Y stage I (though not exceeding the level of significance).

A limitation of our study is the small number of PD patients in H&Y stage I. Thus, the interpretation of these results should be cautious. The results obtained in the frontal plane were similar in PD patients in H&Y stage II and in controls. The visual control effect showed a significant difference.

Orawiec studied a small group of PD patients and found that the difference in sway in the frontal plane between patients and controls was 0.6 mm with sight control and 5.9 mm without sight control [21]. ANOVA showed that the group factor was not significant while the sight factor was significant. The interaction between

the group factor and the sight factor was significant. Increase of sway in the frontal plane was non-significant in both groups [21].

In an analogous study performed in a larger population of PD patients, the difference between patients and controls in sway in the frontal plane was 105.8 mm with visual control and 164.1 mm without visual control. The analysis confirmed significant differences between studied groups, whether tested with or without visual control. The group factor and sight factor were also significant [14].

Total path length was compared among PD patients in H&Y stages I-III and the shortest sway path was found in stage II. Exclusion of visual control shortened the total path length by 25.7 mm in H&Y stage II PD patients in comparison to controls.

Błaszczuk found that the difference in sway of the total path between patients and controls was 162.4 mm with visual control, and 252.3 mm without visual control [14]. ANOVA showed a significant effect of both group and sight factors. Post-hoc NIR test confirmed a significant difference in sway of the total path between PD patients and controls.

Orawiec noted that the difference between two groups in sway of the total path was 66 mm with sight control and 103.7 mm without visual control. Post-hoc test revealed a lack of significant difference between PD patients tested with sight control and controls tested without sight control [21].

Marchese *et al.* [10] and Schieppati *et al.* [22] compared sway in PD patients and controls. Differences in sway were non-significant and were revealed only after dynamic testing. Mitchell [23] and Bouisset [24] documented an increase in all types of sway as a disturbance of the normal correlation between posture and movement performed. According to both authors, disturbances of postural stability due to increased sway in the frontal plane may be compensated by decreased antero-posterior stability. Van Wegan and Schmit, on the other hand, found a difference in amplitudes of frontal sway in both early and advanced disease when compared with matched controls [25,26].

The results suggest that age constitutes an important variable affecting sway in the frontal plane, both in healthy subjects and in PD patients. Sway in PD patients, however, increased with age, while in controls it decreased proportionally.

Marchese did not find a difference in range of sway between PD patients and elderly subjects without parkinsonism, when tested with eyes open and closed [10]. Horak [11], Beckley [12], and Bloem [27] re-

ported sway similar to controls with regard to age of the subjects. We found similar values of sway in analysed planes in our study.

The results show variability of compensatory mechanisms during the development of PD. Variability of this process is characterized by sway in first three PD stages according to H&Y.

To sum up, the control of postural stability is not only the result of the balance between the activity of respective antagonistic groups of muscles that stabilize particular joints, but also the action involving various sensory systems, planning and a learning process [11]. Despite apparent immobility, the human body performs sway related to the integration of the vestibular and visual inputs. Not all PD patients report the full triad of signs, but observed postural disturbances may result in lesser ability to interpret the stimuli at the CNS level [28,29].

The results presented here show that a greater range of sway is not always due to impaired control of posture. Our observations confirm the findings of other authors, who used posturography to assess postural sway in patients with PD. Posturography and testing with and without visual control enable objective assessment of the imbalance, and an understanding of the mechanisms underlying the control of posture [30].

Disorders of balance, posture and related gait disturbance significantly affect the health status and psychological well-being of the patient. Loss of stability and the related propensity to fall frequently lead to decreased motor activity and may contribute to the social isolation of the patient [31-33].

Conclusions

1. Disturbed postural stability was found among studied patients with PD.
2. Visual control significantly affects the parameters of postural stability in PD patients.

Disclosure

Authors report no conflict of interest.

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