Oculomotor Abnormalities in Parkinson’s Disease
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- Ocular movement was studied in 19 patients with Parkinson’s disease and in ten normal controls. Common abnormalities included "hypometric saccade" on the eye-tracking test and on command, "saccadic pursuit," and convergence paresis. Reaction time was longer in patients with Parkinson’s disease than in controls for horizontal saccadic gaze, finger movements, and body movements. Maximal saccadic velocity of horizontal gaze was slower in patients with Parkinson’s disease than in controls. Slowing of the horizontal saccadic movement correlated significantly with increased reaction time of finger and body movements. Correlation of decreased saccadic velocity with increased reaction time of finger movement was found for the finger ipsilateral to the direction of horizontal gaze, but not for the contralateral finger. It is postulated from these facts that bradykinesia also exists in eye movements in Parkinson’s disease.

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Earlier works on ocular movement in Parkinson’s disease were based on the clinical observation of patients with postencephalitic parkinsonism. Among various kinds of oculomotor abnormalities reported, the frequent occurrence of vertical gaze paresis, convergence paresis, oculogyric crisis, and disturbance of pursuit following movement was stressed. Similar abnormalities have been reported in patients with idiopathic parkinsonism. (Parkinson’s disease) , although oculogyric crisis has been found to be rather characteristic for postencephalitic parkinsonism. More recent studies of ocular movement in patients with Parkinson’s disease in which the electromyogram and the electro-oculogram (EOG) were used confirmed the previous clinical observations. However, the pathophysiological mechanism underlying those oculomotor disorders still remains to be clarified.

Basal ganglia are believed to participate in the control of ocular movement, but the neural mechanism is poorly understood. Whether the oculomotor abnormalities seen in Parkinson’s disease are directly related to abnormalities of the nigro-striatal system has not been clarified yet. There is controversy as to whether or not bradykinesia, the most important symptom of Parkinson’s disease, exists in ocular movement as well. The same holds true for rigidity. As far as hand or body movement is concerned, bradykinesia is best reflected by a prolonged initiation time. Therefore, the present study was undertaken to investigate the initiation time of eye movements in Parkinson’s disease as a possible index of bradykinesia. Special attention was directed to the relationship between the reaction time (RT) as well as the saccadic velocity of eye movements and the RT of other movements. Electro-oculographic findings in the patients are also described in comparison with those in the normal controls.

SUBJECTS AND METHODS

Nineteen patients, eight men and 11 women, with Parkinson’s disease were studied clinically and electrophysiologically. Their ages at the time of examination ranged from 49 to 69 years. The majority were receiving antiparkinsonian medications that included levodopa at the time of examination. Ten healthy men, ranging from 42 to 58 years of age, served as a control.

Neuro-ophthalmologic investigations included studies of EOG, RT, and maximal saccadic velocity of the horizontal ocular movement in addition to clinical observations. These tests were carried out in a sitting position, with the patient’s head fixed in a head-hold. Cup electrodes were placed on the outer canthi and on the glabella for recording the horizontal ocular movement, and above and below each eye for the vertical movement. The EOG was

![Graph](https://example.com/graph.png)

**Fig 1.**—"Cogwheel pursuit threshold," frequency of target movement at which smooth pursuit movement just began to be interrupted by saccadic movements, in Parkinson’s disease and normal controls (NC). For akinesia, rigidity and tremor, + + indicates marked degree, + moderate degree, and ± mild degree or no, respectively. Cases at 1.0 Hz are ones whose smooth pursuit movement was not interrupted at 1.0 Hz or above. Note that all five cases with markedly decreased cogwheel pursuit threshold showed more than moderate degree of rigidity, but mild or no tremor.
Fig 2.—Electro-oculogram in patient with Parkinson's disease. Saccadic movement on eye-tracking test is grossly disorganized in stepwise or hypometric pattern. On verbal command, saccadic movement is slowed and occasionally hypometric. H indicates horizontal original curve; dH, horizontal velocity curve; and T, target movement. Upward deflection shows leftward movement, and downward rightward.

Fig 3.—Electro-oculogram of patient with Parkinson's disease. Saccadic movement on eye-tracking test, shown on top three tracings, is hypometric. Smooth pursuit movement on following target moving sinusoidally at 0.25 Hz, shown at bottom, is interrupted by small saccadic movements.

RESULTS
EOG Findings

In all subjects of the normal control group, EOG was normal at rest, on
forward gaze at the primary position, and on verbal command to make a saccadic movement in all directions. But on the eye-tracking test, saccadic movement was hypometric in one subject for the horizontal direction and in two for the vertical direction, although to a mild degree. Smooth pursuit movement was abnormal in two subjects for the horizontal direction and in seven for the vertical direction, showing a moderately decreased cogwheel pursuit threshold frequency (Fig 1). Convergence was moderately insufficient in one subject and mildly impaired in two. Oculocephalic response (OCR) was normal in all subjects both for the horizontal and vertical directions. Optokinetic nystagmus (OKN) was normal in all subjects for the horizontal direction but insufficient in two subjects for the vertical direction.

In the patient group, the EOG at rest and that on forward gaze at the primary position were normal in all cases. There was no oculomotor insufficiency. The saccadic movement in response to verbal command was abnormal in five of 16 subjects examined for the horizontal direction and also in five of 16 for the vertical direction. The abnormalities commonly included "hypometric saccade" and slowing of the saccadic movement (Fig 2). In one case, voluntary upward gaze was considerably limited, although the OCR was intact. Convergence paresis was found in 11 (69%) of 16 patients examined, it being complete in four and moderate in seven. On the eye-tracking test, the saccadic movement was hypometric in 16 of 18 patients examined for the horizontal direction and in 13 of 18 for the vertical direction (Fig 2, 3). The smooth pursuit movement was found to be saccadic or stepwise in six of 18 patients examined for the horizontal direction and in 12 of 18 for the vertical direction (Fig 3). None of the patients showed hypermetric saccades. The cogwheel pursuit threshold for horizontal movement was substantially reduced in five patients and moderately reduced in one (Fig 1). Oculocephalic response was normal in all patients for both the horizontal and the vertical directions. Optokinetic nystagmus was normal in most patients, was absent to all directions in one patient, was insufficient for the vertical direction in another, and was insufficient only for the upward direction in two other patients.

Relationship between the cogwheel pursuit threshold and the intensity of each cardinal symptom in Parkinson's disease. Negative correlation was found between the two parameters.

Fig 4.—Reaction time in patients with Parkinson's disease (P) and in normal controls (NC). For all types of movements (eyes, finger and body) reaction time is significantly prolonged in patient group as compared with control.

Fig 5.—Maximal saccadic velocity of horizontal eye movement in Parkinson's disease (P) and normal controls (NC). Saccadic movement is significantly slower in patient group than in control.

Fig 6.—Relationship between maximal saccadic velocity of horizontal eye movements and reaction time (RT) of body movements in patients with Parkinson's disease. Negative correlation was found between the two parameters.
disease is shown in Fig 1. Five patients showed a significantly reduced cogwheel pursuit threshold. Four of them belonged to the group with neck rigidity of great intensity and the other one to the group with moderate rigidity. On the other hand, all of them belonged to the group with mild or no hand tremor. No particular association was found with the intensity of bradykinesia.

**RT**

The mean RT for horizontal saccadic eye movement, leftward and rightward inclusive, was 318 ms (SD of 54 ms) for the patient group whereas it was 248 ms (SD of 27 ms) for the control. Mean RT for the finger movement, both sides inclusive, was 352 ms (SD of 76 ms) for the patient group vs 258 ms (SD of 32 ms) for the control. The mean RT for body movement was 1,026 ms (SD of 109 ms) for the patient group and 843 ms (SD of 61 ms) for the control. In all three kinds of movements, the RT was significantly longer in the patient group than in the control group ($P < .001$, Mann-Whitney test$^2$) (Fig 4).

A positive correlation between the RT of eye movement and that of body movement was noted, but it was not statistically significant ($r = .44; .05 < P < .1; t$ test). The correlation between the RT of eye movement and that of finger movement was not significant ($r = .29; .1 < P < .2; t$ test).

**Maximal Saccadic Velocity**

The mean maximal saccadic velocity of the horizontal eye movement, leftward and rightward inclusive, was 337 degrees per second. (SD of 64 degrees per second) for the patient group, whereas it was 392 degrees per second (SD of 49 degrees per second) for the normal control. The difference was statistically significant ($P < .005; t$ test) (Fig 5).

There was a negative correlation between the maximal saccadic velocity and the RT of eye movements, but it was not statistically significant ($r = -.32; .05 < P < .1; t$ test). On the other hand, the maximal saccadic velocity was found to be significantly correlated with the RT of body movement ($r = -.51; P < .05; t$ test) (Fig 6). As for finger movement, there was a significant negative correlation between the maximal saccadic velocity and the RT only of the finger ipsilateral to the direction of the horizontal gaze ($r = -.39; P < .05; t$ test) (Fig 7). But the maximal saccadic velocity was not significantly correlated with the RT of the contralateral finger ($r = .28; .1 < P < .2; t$ test).

**Comment**

Corin et al$^9$ found some oculomotor abnormalities in 75% of 70 patients with Parkinson’s disease. The most common abnormalities that they reported included an impairment (such as jerkiness, cog-wheeling, and limitation) of upward gaze on command to “look up,” blepharospasm, an impairment of horizontal gaze on command (although to a lesser extent than the upward gaze), an impairment of upward smooth pursuit, abnormal OKN, and disturbance of convergence. Similar abnormalities have been reported by several investigators.$^{10-15}$ The present EOG studies also showed oculomotor abnormalities in a large proportion of patients. The most conspicuous abnormalities included hypometric saccade on the eye-tracking test as well as on command and saccadic or cogwheel pursuit in both vertical and horizontal directions. Convergence was impaired in 70% of the patients. Reflex movements such as OCR and OKN were found to be intact in the majority of patients, suggesting that dysfunction in the supranuclear oculomotor system is responsible for these oculomotor abnormalities.

Although hypometric saccade and saccadic pursuit are frequently encountered in Parkinson’s disease,$^{11,14,16}$ similar abnormalities have also been described in pathological involvement of other than the basal ganglia. For example, these abnormalities are seen in cerebellar lesions as well.$^{17-19}$ Troost et al$^{20,21}$ found hypometric saccade and saccadic pursuit in the rightward and leftward directions, respectively, in a patient with left hemispherectomy with basal ganglia remaining intact. It is quite surprising that some subjects of the normal control group in the present study showed hypometric saccade and saccadic pursuit, although to a lesser extent than subjects of the patient group. Saccadic vertical pursuit on the eye-tracking test was particularly common. Therefore, neither hypometric saccade nor saccadic pursuit seems to be related solely to a lesion in the basal ganglia.

Since Bing$^{24}$ proposed the term “okuläres Zahnradphänomen” in 1923, saccadic pursuit in Parkinson’s disease has been designated as cogwheel pursuit. However, whether or not this oculomotor phenomenon is identical to the cogwheel rigidity seen in the extremities of the patients with Parkinson’s disease has not been resolved. The present study paid special attention to the cogwheel pursuit threshold, i.e., the
frequency of target movement at which the smooth pursuit movement just began to be interrupted by saccadic movements. We found five patients with significantly reduced cogwheel pursuit threshold. It is noteworthy that all these patients had considerable rigidity in the neck muscles, but mild or no hand tremor. The conclusion as to whether rigidity really exists in the extracocular muscles in Parkinson's disease awaits further study based on a larger number of cases.

In contrast to the previous observations, in which gaze difficulty on command rather than on following targets was stressed, the present study demonstrated abnormalities of saccadic movements more on the eye-tracking phenomenon than on verbal command. In several elaborate neuropsychological tests investigating the sensorimotor control of hand movements in Parkinson's disease, it was shown that the difficulties were more often attributable to a deficiency of central programming or processing than a lack of motor coordination.

Therefore, it is conceivable that the present finding of more difficulty with eye-tracking performance than on verbal command might reflect a deficiency in central processing of visual information in the oculomotor task.

The most remarkable finding in the present study is the quantitative demonstration of an increased RT and a decreased maximal saccadic velocity of horizontal gaze in Parkinson's disease. The delayed initiation of gaze and the slowing of the saccadic movement in this disease have been reported in the literature, although not by quantitative analysis. As far as hand or body movement is concerned, an increased time to initiation of movement or RT and an increased motor time in Parkinson's disease have been correlated with bradykinesia.

Therefore, it is conceivable that the delayed initiation and slowing of eye movements is related to oculair bradykinesia. The present study on correlation of eye movements with hand and body movements in Parkinson's disease demonstrated, for the first time to our knowledge, a negative correlation between the maximal saccadic velocity of the horizontal gaze and the RTs of finger and body movements. In other words, the slower the saccadic eye and body movements, the longer the RTs of finger and body movements. It is especially noteworthy that the maximal saccadic velocity correlated with the RT of the finger ipsilaterally to the direction of horizontal gaze, but not with that of the contralateral finger. These facts seem to favor the hypothesis that bradykinesia also exists in eye movements of patients with Parkinson's disease.

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Nonproprietary Name and Trademarks of Drug

Levodopa—Bendopa, Dopar, Larodopa.

References