PHYSIOLOGY

Analysis of Trajectories of Eye, Head, and Hand Movements for Early Diagnosis of Parkinson's Disease

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Relationships between eye, head, and hand movements in patients with stages I-II Parkinson's disease were studied using an original method. The tests for individual movements in patients and healthy individuals yielded similar results, while coordination test revealed significant differences.

Key Words: *saccades; coordinated movements; multiple saccades; Parkinson's disease*

Parkinson's disease (PD) is one of the most prevalent neurodegenerative diseases. Its clinical manifestations are caused by deficiency of dopamine production resulting from damage to 60-80% neurons in the compact part of the substantia nigra. It is important to find a way to predict the disease before neuron degeneration in this structure reaches the critical level.

We studied some aspects of early preclinical diagnosis of PD and analyzed changes in electrophysiological parameters of movements at the early stages of this disease.

MATERIALS AND METHODS

The study was carried out in 28 volunteers: 12 healthy subjects and 16 patients with stages I-II PD [3]. Motor activity was evaluated in special tests using a programmed complex [1]. The capacity to fix eyes on a target jumping horizontally (by 40°) from the center to periphery without moving head (*i.e.* by saccades alone) and to smoothly move the head to the left and right with the eyes fixed on the target moving synchronously with the movements of the head (*i.e.* moving only the head) was tested. One more test evaluated the capacity to move a cursor by memory to the peripheral target with eyes closed, by isolated movements of the hands using extraretinal information (the position of the target was memorized after several analogous sessions with eyes open); and coordinated movement (transfer of the cursor from the central target to peripheral one) with participation of the eyes, head, and hand was tested.

Hence, movements of individual organs (eyes, head, or hand alone) and then coordinated movements of all organs were evaluated. The latent period, duration, and accuracy of movements were recorded. All tests were performed first to the right and then to the left; 20-25 sessions were made in each test. Sessions with multiple saccades were recorded separately.

The data were statistically processed using Statistica 6.0 software.

RESULTS

Latencies and duration of saccades of each eye varied by 10-30 msec in each session for patients, but not for healthy volunteers, in whom the differ-

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TABLE 1. Eye Saccades (Testing of Isolated Movements of the Eyes; msec; *M*±*m*)

Saccades		Healthy volunteers	Patients with early PD stages
Left eye to the right	latent period	176.7±9.1	192.6±31.6
	duration	103.3.3±11.6	117.4±23.4
Right eye to the right	latent period	182.8±8.4	188.2±29.2
	duration	112.1±10.9	130.1±41.3
Left eye to the left	latent period	165.6±7.2	187.0±30.9
	duration	106.4±7.8	124.9±33.2
Right eye to the left	latent period	174.9±8.2	180.2±8.5
	duration	104.0±7.5	121.7±29.4

ences were negligible (several milliseconds; Table 1). Despite minor increase in the test parameters in PD patients, statistical analysis showed no significant difference between healthy individuals and patients with initial stage of the disease, which was presumably due to greater variability of values in PD patients in comparison with the control group. Increased variability indicates initial disorders in the saccadic system: 15% saccades were double in PD patients *vs.* 3% in the control.

The frequency of head movements in the horizontal plane decreased significantly in some patients (1.2-1.4 times) in comparison with this parameter in healthy volunteers, while fixation of the eyes and staring at the target were about the same (judging by electrooculogram). Electrooculogram showed just individual deviations of the gaze presenting as a slight drift (not a deviation from the normal; Fig. 1).

The mean latencies were virtually the same in healthy volunteers and PD patients; so were the amplitudes of hand movements to the target (Fig. 2). The durations of hand movements varied significantly for the groups: 912.0±62.1 msec in the control *vs.* 1083.0±215.4 msec in PD patients. These data can indicate initial disorders in movement programming/realization and intactness of the kinesthetic analyzer in patients with the early PD stage [4]. The parameters of individual movements in progressive PD (stages III-IV [3]) differed significantly from those in healthy volunteers.

All parameters of coordinated movements of PD patients differed significantly from those in healthy volunteers (Fig. 3). An increase in the number of multiple saccades [2] was observed, which reached 5% in healthy volunteers and 34% in PD patients.

It seems that changes in the movement parameters at the initial stage of the disease are minor and virtually did not differ from the age-specific normal values. Presumably, intensive compensatory and repair processes in the brain prevent rapid development of the disease. Nevertheless, all studied movements alone (isolated movements of the

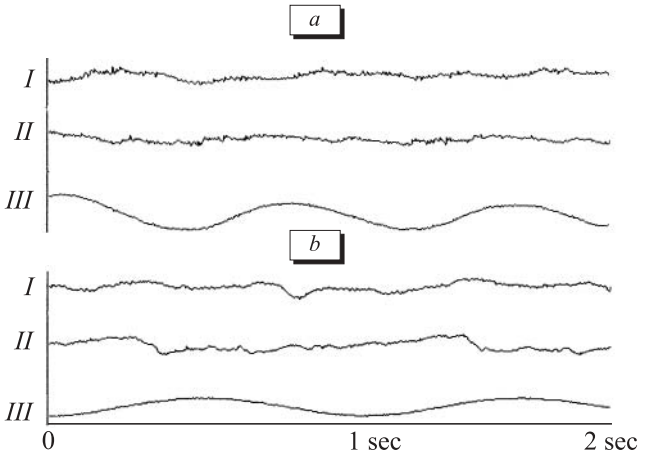

Fig. 1. Smooth movements of the head in the horizontal plane to the left (ascending part of the curve) and right (descending part), during which the stare was fixed at the target moving synchronously with the head movement in testing of isolated movement of the head. *a*) healthy volunteer; *b*) PD patient. *I*) left eye; *II*) right eye; *III*) head.

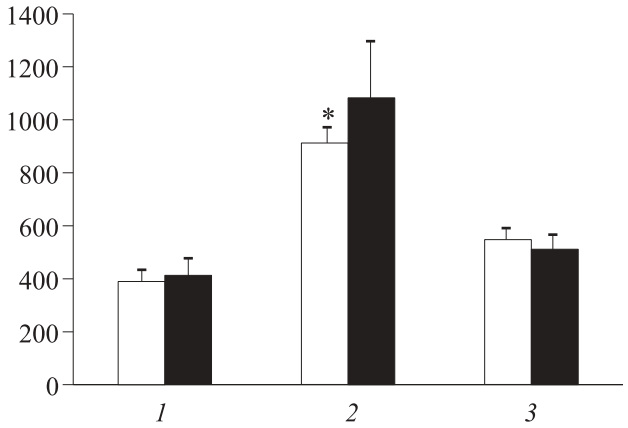

Fig. 2. Testing of isolated movement of the hand. *1*) latency; *2*) duration; *3*) amplitude of hand movement. Light bars: healthy volunteers; dark bars: PD patients. Here and in Fig. 3: **p*<0.05 compared to healthy volunteers.

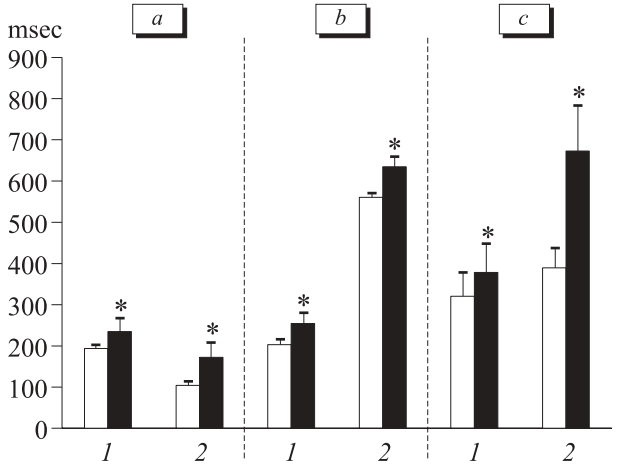

Fig. 3. Index of coordinated movement of the eyes (*a*), head (*b*), and hand (*c*) of healthy volunteers (light bars) and PD patients (dark bars). *1*) latency; *2*) duration.

eyes, head, or hand) are realized with minimum not always detectable errors. Realization of these "simple" movements in complex leads to superposition of errors, which causes significant motor disorders. This fact indicates that realization of coordinated movement with superposition of different errors sharply increases the probability of detecting motor disorders at the earliest stages of PD. It seems that disorders in motor coordination (latency, duration, accuracy, multiple saccades, multi-staged pattern) during degeneration of the substantia nigra dopaminergic neurons can be regarded as a marker of early PD stage. Further studies are needed for verification of our hypothesis.

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