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EFFECT OF NIGHT SHIFT-RELATED TIREDNESS ON EYE SACCADES

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Parameters of saccades (latency, amplitude, duration, and velocity) were measured using a saccadometer in 32 nurses (30 women and 2 men) before and after a night shift. The mean latency of saccades was found to significantly increase after this period (209.6 ± 6.84 vs. 188.6 ± 6.08 msec, $P = 0.002$); the same was found with respect to the saccade duration (55.0 ± 0.97 vs. 54.2 ± 1.23 msec, $P < 0.05$). Thus, stress and sleep deprivation noticeably influence the parameters of saccades; the latter, nonetheless, remain within a physiological range. Considering that a number of brain structures are involved in the control of saccade parameters, the above-described modulations of saccades can be potentially used as generalized indices characterizing the level of brain tiredness.

Keywords: saccades, saccade mechanisms, latency, duration, brain tiredness.

INTRODUCTION

Saccades are rapid changes of angular positioning of the eyeballs leading to proper alignment of the line of sight of both eyes with the respective fovea [1]. During saccades, visual perception is temporarily blocked to prevent loss of visual acuity [2].

A number of studies demonstrated that the parameters of saccades are significantly influenced by the functional status of the CNS. This is quite natural because a number of cerebral structures are involved in the generation of this motor phenomenon and in the control of its parameters. Among these structures, there are nuclei of craniocerebral nerves III, IV, and VI and also structures of the upper brain levels providing descending control of the latter nuclei [3]. The parameters of saccades demonstrate significant personal diversity. Analysis of the eye movements is utilized in the assessment of various diseases, including Alzheimer's disease, brain trauma, attention deficit/hyperactivity disorder (ADHD), and others. A number of factors, including normal/abnormal sleep, tiredness, stress, illness, medications, diet, etc., contribute to the general state of the CNS and should affect the parameters of saccades [1–4].

The literature available contains insufficient information regarding the influence of stress and sleep deprivation on the parameters of saccades. Considering this, we examined the effects of night shift (an ordinary duty of nurses) on the latency, amplitude, and velocity of saccade eye movements in a group of the respective medical workers; it was believed that the results of such a study would promote the development of a simple tool to objectively measure the influence of tiredness on the the functions of the CNS.

METHODS

Thirty-two volunteers, night shift nurses of the Department of Imaging Studies, Emergency, and Mass-Event Medicine Trauma Center of the University Hospital in Krakow, took part in the study. Among them, there were 30 women and 2 men. Their mean age (± s.e.m.) was 38.9 ± 1.82 years; on average, they had 14.6 years of experience (range 1-38). A standard technique of saccadometry was used. Subjects sat in a chair with their head in a neutral position. Laser light of the saccadometer was displayed on a wall (about 2 m in front of the examined nurses) and was used as a primary target of their gaze. The studies were performed in a moderately illuminated quiet room. The measurements were carried out before and immediately after a 12-h-long night shift.

Numerical data are shown below as means ± ± s.d./s.e.m. The Wilcoxon signed-rank test was used in comparisons of the saccade parameters

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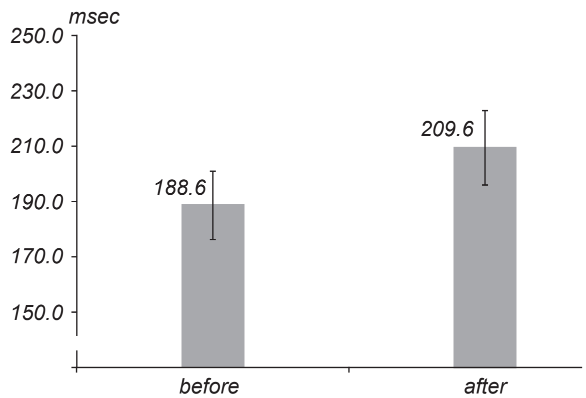
(latency, duration, amplitude, and velocity) because distributions of the parameters showed deviations from normality in most cases. Group differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

The main result of our measurements is that the mean latency of saccades and their duration after the night shift became significantly longer than those before this period ($P = 0.002$ and $P < 0.05$, respectively). At the same time, the promptness of saccades became significantly smaller ($P < 0.001$). No significant differences between the pre- and post-amplitudes and velocities of saccades were found.

In the examined group, the mean latency of saccades under resting conditions was 188.6 ± 6.08 msec, while after the night shift it was significantly longer, with mean 209.6 ± 6.84 msec (M ± ± s.e.m.). The latency of reflexive saccades in healthy subjects ranges between 150 and 300 msec [4]. For predictive saccades, it can become as short as 60 msec. The latency increases with age [5]; this parameter is influenced by various factors, including illumination brightness, size and contrast of the stimulus, type of the latter (visual vs. auditory), initial position of the eyeballs, predictability of the target movement, distractors, and instructions given to the subject [6]. In our study, all the above factors where either identical or eliminated, and the saccade latency was directly influenced exclusively by night shift-related tiredness.



F i g. 1. Diagram of the mean latencies (± s.e.m.) of saccades before and after a night shift.

Р и с. 1. Латентні періоди сакад дó та після нічного чергування (середні ± похибка середнього).

The duration of saccades in healthy subjects does not exceed 100 msec. In our study, the mean duration significantly increased due to tiredness (55.0 ± 0.97 vs. 54.2 ± 1.24 msec before the night shift; $P < 0.05$). The duration and velocity of saccades do not undergo voluntary control. Many factors can influence these parameters even in the same individual. Saccades are slower in darkness, when they are directed toward the last remembered position of the target, and when directed oppositely with respect to the stimulus [6]. The environmental brightness and type of target were the same at all our measurements.

According to Camors et al. [7], the dynamics of initiation of saccades are apprehended through the promptness, which corresponds to the inverse of the onsets (also called latencies, or reaction times). The promptness values are usually normally distributed and positively related to the speed of initiation. The onsets have right-skewed distributions and are negatively related to the speed of initiation [7]. In our study, the night shift significantly influenced the promptness; the latter decreased (post- 5.6 ± 0.12 vs. pre- 6.0 ± 0.16 Hz, $P = 0.0013$).

There are four groups of saccades [8].

(i) Internally-guided (or volitional/voluntary-guided) saccades are generated in the direction of a cautiously selected target. This group includes cued saccades, anti-saccades (generated in the direction opposite to the target), predictive (anticipatory) saccades (generated in advance of a predicted target or in search of a target in a given place), and commanded saccades (initiated by a command).

(ii) Externally guided (or reflexive) saccades are generated in response to an unexpected visual, auditory, or tactile stimulus.

(iii) Spontaneous saccades are present in the absence of a target; they are generated to scan for a target and are present under resting conditions, during motor activity, or REM sleep.

(iv) Quick phase nystagmus occurs during vestibular stimulation or under pathological conditions.

Saccade eye movements are ballistic and belong to a class of preprogrammed movements. The system responsible for programming of saccades is organized hierarchically and includes four levels. The first level immediately controls the performance of saccades and includes the nuclei of craniocerebral nerves III, IV, and VI that excite the oculomotor muscles. The second level of the saccade system consists of brainstem structures providing supranuclear control of eye movements. These are nuclei of the brainstem

Saccade Parameters before and after a Night Shift
Параметри сакад дó та після нічного чергування

Parameters	Before a night shift					After a night shift					Wilcoxon signed rank test, *P*
	Mean	s.d.	s.e.m.	Median	Quartiles 1–3	Mean	s.d.	s.e.m.	Median	Quartiles 1–3	
Latency, msec	188.6	34.4	6.08	182.5	165.5–203.5	209.6	38.7	6.84	198.0	178.0–238.0	**0.0024**
Promptness, Hz	6.0	0.9	0.16	6.0	5.2–6.7	5.6	0.7	0.12	5.6	5.2–6.1	**0.0013**
Duration, msec	54.2	7.0	1.24	52.0	50.0–56.0	55.0	5.5	0.97	55.0	52.0–57.5	**0.0489**
Amplitde, deg	11.4	3.5	0.62	10.6	9.4–12.0	12.3	4.8	0.85	10.5	9.9–12.7	0.1714
Max velocity, deg/sec	417.0	141.0	24.93	388.0	343.0–428.5	443.1	187.4	33.13	390.5	343.5–441.0	0.3795
Mean velocity, deg/sec	215.8	69.3	12.25	202.5	175.0–225.0	232.1	100.0	17.68	204.5	174.0–231.0	0.3991

reticular formation, pontine structures, and some nuclei of the midbrain tegmentum. This level controls integral coordinated movements of both eyes.

The third and fourth levels of the mentioned system perform descending control of the two lower levels (corresponding to the brainstem saccade generator). These are the *colliculus superior*, basal ganglia, cerebellum, *corpus callosum*, *capsula interna*, *pulvinar*, and some thalamic nuclei, on the one hand, and a few cortical areas related to the control of the eye movements, on the other hand.

Thus, a number of important cortical structures belonging to different brain levels are involved in the control of saccade movements. Consequently, changes in the parameters of saccades induced by one factor or another may be considered as certain integral indices characterizing the general state of the cerebral mechanisms. Modifications of saccadic movements reflect neurodegenerative processes induced by physiological aging, mental disorders, and motor disorders. These phenomena may outperform other motor symptoms and can serve as specific markers of the disease. In our case, changes in the parameters of saccades reflect the development of stress/sleep deprivation-induced tiredness of the respective brain mechanisms. Our results open a potential possibility of application of the saccade measurement for the assessment of brain tiredness.

This study was carried out in accordance with the statements of international documents regulating the rules of research with the involvement of humans and was approved by the Bioethical committee of the Jagiellonian University Medical College (28.05.2015, No. 122.6120.106.2015). All examined subjects gave their written informed consent for their participation in the tests.

The authors of this study, A. Skrzypek, M Szeliga, K. Jabłoński, and M. Nowakowski, confirm that the research and publication of the results were not associated with any conflicts regarding commercial or financial relations, relations with organizations and/or individuals who may have been related to the study, and interrelations of co-authors of the article.

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ВПЛИВ ВТОМИ, ПОВ'ЯЗАНОЇ З НІЧНИМИ ЧЕРГУВАННЯМИ, НА САКАДИЧНІ РУХИ ОЧЕЙ

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Р е з ю м е

Використовуючи сакадометр, вимірювали параметри сакад (латентний період, амплітуду, тривалість та швидкість) у 32 молодших медичних працівників (30 жінок, два чоловіки), що чергували в нічні зміни. Виявилося, що середній латентний період після такого чергування вірогідно збільшувався порівняно з таким до чергування (209.6 ± 6.84 проти 188.6 ± 6.08 мс, $P = 0.002$). Паралельно збільшувалася середня тривалість сакад (55.0 ± 0.97 проти 54.2 ± 1.23 мс, $P < 0.05$). Отже, стрес та позбавлення сну істотно впливають на параметри сакад, хоча останні й залишаються в межах фізіологічної норми. Беручи до уваги залученість у контроль параметрів сакад численних мозкових структур, зазначені вище модуляційні зміни сакад можуть знайти застосування як генералізовані показники, що характеризують рівень втоми мозку.

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