How Normal are "Normal" Square Wave Jerks?

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Fifty normally sighted young subjects underwent horizontal electro-oculographic (EOG) examination to investigate fixation stability of the saccadic system. The number of square wave jerks (SWJ) and saccades per minute were calculated in three clinically used test conditions: (1) with a fixation point; (2) in darkness; and (3) with eyes closed. SWJ were recorded in all conditions. The highest number of SWJ per minute were found in darkness and with closed eyes. The analysis of the findings shows a range of normalcy for these three clinically used EOG conditions from which pathology can be inferred. Invest Ophthalmol Vis Sci 30:1009-1011, 1989

The occurrence of inappropriate saccadic couplets has long been clinically observed during ophthalmoscopy and was recorded as early as 1916.1 These couplets have been termed "Zickzackbewegungen"2 and "Gegenriicke," or square wave jerks (SWJ)3 and are generally characterized as inappropriate saccades that take the eyes off the target, being followed by a nearly normal intersaccadic interval (approximately 200 msec) and then by a corrective saccade that brings the eyes back to the target.4

The majority of studies, including a review of the literature,5 emphasize the occurrence of SWJ in connection with neuropathology, appearing when the eyes are closed as well as during fixation.5,6,9

Their occurrence in normals, with few exceptions,11,12 has not been a focus of interest. Differences relating to the frequency of SWJ and age in normals were reported using an infrared reflection method.11 SWJ were observed in recordings from two of 12 elderly subjects (ages 65 to 79; mean age: 71), and 5 of 17 younger subjects (ages 20 to 52; mean age: 32) (24% of the entire sample). In darkness, SWJ were replaced by drifts and saccades.

Using a similar recording method, a more recent study12 examined the effects of various fixation stimuli on SWJ in 16 normal subjects ranging in age from 18 to 74 years. Target size, over 18 min of arc, as well as total darkness produced enlarged SWJ of more than 0.5° in six out of the 16 subjects.

The purpose of this study was to describe a range of normalcy by evaluating involuntary, spontaneous, horizontal eye movements in young normals under specific clinically used testing conditions. Subjects' age and size of the fixation target were controlled. Only young subjects participated to rule out possible ocular motor instabilities that may be due to age. The visual angle subtended by the fixation target was small to avoid eye movement from edge to edge of the target.

SWJ in normals are subtle and can be missed clinically.13 However, they are readily apparent using eye movement recordings.

Materials and Methods

Spontaneous eye movements (0.5° and above) were quantitatively recorded using a Tönnies (Freiburg, West Germany) two-channel electro-oculogram (EOG) and DC-coupled, amplified electronics with a high cut-off at 30 Hz (−3 dB). A headrest was employed.

Subjects

Fifty university students (25 male, 25 female) between the ages of 21 and 37 years (mean age: 25.1 years) volunteered for this experiment. Subjects were required to have full vision without glasses or with contact lens correction and no history of nystagmus or vestibular disturbance. All participants were unpaid volunteers, being fully informed about the nature of the procedure and their full consent was obtained before the beginning of the experiment. They were naive to the purpose of the experiment.

Procedure

The following test conditions were employed:

1. The subject was instructed to fixate binocularly in the primary position (PP) at a fixation target (1.5
cm in diameter) 1.5 m away (visual angle: 0.57°) in a lighted room.

2. The subject was instructed to look straight ahead in a completely unlighted room. Neither a fixation point nor any other light source was available.

3. The subject had both eyes closed.

The registration time for each test condition was 2 min. All registrations were conducted by a naive assistant who was not informed as to the underlying purpose of the experiment.

The number of SWJ and isolated saccades per minute (that is, saccades that were not a part of a SWJ) were calculated in each test condition. Corrections for drift were not included in any calculation.

A naive judge analyzed the EOG recordings to obtain an objective assay of involuntary eye movements. Accordingly, the sequence of EOG recordings chosen for evaluation for every subject, in all conditions, was held fixed through the following rating procedure: the first 30 sec of recording time was disregarded. Eye movements were calculated from the second 30 sec of recording time, ignored for the third 30 sec interval, and calculated for the fourth consecutive 30 sec interval. Nine registrations out of the 50 had a shorter recording time. For these recordings, a 10 sec interval was used for rating.

### Results

SWJ occurred in all conditions, with the highest percentage recorded in darkness and eyes-closed conditions. The mean frequency per minute, duration and amplitude are displayed in Table 1. EOG recordings, with examples of typical SWJ in normals under the three test conditions, are displayed in Figure 1. The mean and median frequency and mean amplitude of saccades in the three test conditions are reported in Table 2. The saccade data shown here were not part of a SWJ but single, isolated intrusions.

### Discussion

EOG recordings of involuntary eye movements from 50 normal subjects were analyzed in terms of SWJ and saccades. SWJ occurred in normal individuals not only when the eyes were closed and in darkness with the individual looking straight ahead but also when looking at a small fixation point in a lighted room.

In EOG recordings, a finding of more than 16 SWJ per min should be considered abnormal during fixation, and over 20 SWJ per min should be considered abnormal in darkness or when the eyes are closed.

Some differences were found between these findings and those of Herishanu and Sharpe. They recorded SWJ in elderly and young normal subjects. The young group consisted of 17 individuals between the ages of 20 and 52 years (mean age: 32 years) who were examined in a lighted room with a target at the midpoint and at 5°, 10° and 20° to either side of the midpoint. SWJ were recorded in five of the 17 young subjects (29.4%) as compared with 30 of the 50 subjects (60%) in this study (21 to 37 years; mean age: 25.1 years) who were examined when the target was only at the midpoint. No significant differences were found in the mean amplitude (t = 0.479, df = 33, n.s.) and frequency per min (t = 0.638, df = 33, n.s.) of SWJ in both studies. Although the difference in the

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### Table 1. SWJ findings for 50 normal subjects under the three test conditions (the mean scores include one standard deviation)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage of sample</th>
<th>Mean frequency/min</th>
<th>Mean duration</th>
<th>Mean amplitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP with fixation point</td>
<td>60</td>
<td>6.1 ± 4.8</td>
<td>211.7 ± 91.1 msec</td>
<td>1.38° ± 0.96°</td>
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<tr>
<td>Lights out</td>
<td>72</td>
<td>7.4 ± 5.3</td>
<td>290.9 ± 101.4 msec</td>
<td>1.81° ± 1.07°</td>
</tr>
<tr>
<td>Eyes closed</td>
<td>74</td>
<td>7.6 ± 6.6</td>
<td>253.1 ± 94.8 msec</td>
<td>1.63° ± 0.84°</td>
</tr>
</tbody>
</table>

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Fig. 1. Example of typical EOG recordings of normal SWJ (arrow): (a) in the primary position with a fixation point, (b) in darkness, and (c) with the eyes closed.
percentage of subjects with SWJ recordings could be due to the variability in age and number of the “young” subjects in each sample, it may reflect the difference in recording procedure. This point will be addressed below.

A more striking difference between Herishanu and Sharpe’s and our findings occurred in darkness. This condition consistently stimulated an increase in the number of SWJ in the current study as compared with the replacement of SWJ with drifts and saccades in the Herishanu and Sharpe report. It seems likely that the specific instruction “to hold the eyes still” in the cases when frequent saccadic intrusions were evident may have damped the production of SWJ in darkness as well as in the light in the Herishanu and Sharpe study. This suggestion is supported by a study of SWJ in patients by the same authors, who found some evidence of reduced frequency of SWJ with specific instruction. Only large amplitude SWJ were evident in darkness in patients with cerebral lesions.

However, most studies involving patients, using various methods of measurement, found an increase of fixation instability in darkness. This was also the case in a recent study with normal subjects recruited from a wide age range, using an infrared reflection technique. In darkness, a mean frequency of 20 SWJ/min was reported.

In conclusion, investigations focusing on normal eye movement can serve as an essential baseline statistic defining a range of normalcy from which pathological oscillations can be inferred.

Key words: square wave jerks, saccadic instability, microsaccade, involuntary eye movement, fixation instability

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Table 2. Mean and median scores of involuntary spontaneous saccadic eye movements in 50 normal subjects under EOG testing conditions (the mean scores include one standard deviation)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage of sample</th>
<th>Mean frequency/min</th>
<th>Mean amplitude</th>
<th>Median frequency/min</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP with fixation point</td>
<td>44</td>
<td>4.41 ± 4.57</td>
<td>1.44° ± 1.06°</td>
<td>3</td>
</tr>
<tr>
<td>Lights out</td>
<td>84</td>
<td>8.50 ± 5.71</td>
<td>1.78° ± 0.94°</td>
<td>6</td>
</tr>
<tr>
<td>Eyes closed</td>
<td>48</td>
<td>5.42 ± 4.41</td>
<td>1.77° ± 0.97°</td>
<td>4</td>
</tr>
</tbody>
</table>

References