Electro-oculographic measures in patients with chronic whiplash and healthy subjects: a comparative study

T Prushansky, Z Dvir, E Pevzner, C R Gordon

Background: Despite their high incidence, costs, and long-lasting disability, whiplash associated disorders (WAD) lack an identifiable objective pathology that explains their acute or chronic symptoms.

Objective: In view of previous suggestions of a possible effect of neck torsion on several electro-oculography (EOG) parameters, the main objective of this study was to examine their applicability in differentiating patients from uninvolved subjects.

Methods: Smooth pursuit and saccadic eye movements were assessed in 26 patients with chronic WAD and 23 healthy subjects. All tests were executed in three neck positions: neutral and rotations to left and right.

Results: Neck torsion did not influence eye movement performance of either the WAD or healthy groups. However, compared with the healthy group, patients with WAD had significantly lower smooth pursuit velocity gain (SPVG) (p = 0.01) and prolonged saccadic latency (p = 0.001), irrespective of neck position.

Conclusions: Despite scattered differences that reached significance, the electro-oculographic measures used in this study do not seem to offer a clinically relevant method for differentiating between patients with WAD and normal subjects.

Whiplash injury is a controversial clinical entity lacking an identifiable pathology that can explain either its acute or chronic symptoms, such as neck pain and stiffness, headache, psychological and cognitive disorders, dizziness, and eye movement disorders. Although some of these may be quantitatively assessed there is a lack of information relating to the sensitivity and specificity of various tests used for delineating valid complaints from those that may not be objectively corroborated. Although various studies have tried to develop objective verification tests, none has yielded clear cutoff scores according to which the disorders could be confirmed.

One area relating to the verification of whiplash injury is based on a controversial theory, indicating that compromise to the cervical afferent system may result in cervical dizziness and eye movement disorders. Applying this theory, the smooth pursuit neck torsion (SPNT) test was used to compare patients with whiplash with healthy subjects. Smooth pursuit velocity gain (SPVG) was measured with the neck positioned at neutral versus 45° rotations to the right and left. The outcome criterion was the difference between the average gains obtained in these positions (SPNTdiff).

In patients, neck torsion significantly reduced the SPVG compared with the neutral position, but this was not the case in controls, allowing an effective differentiation of patients from normal subjects, in addition to patients with non-traumatic neck complaints.

Based on these studies, in addition to our particular interest in cervical motion and preliminary observations indicating that the SPNTdiff might not be as powerful a cutoff, the objectives of this study were: (1) to examine the effect of neck torsion on smooth pursuit and saccadic eye movement measures in patients with chronic whiplash associated disorder (WAD); (2) to compare the findings with those derived from a group of normal subjects; and (3) to examine the applicability of these parameters for the purpose of differentiating patients from uninvolved subjects.

METHODS

Patients

Twenty six consecutive patients with chronic WAD as a result of car accidents (10 men and 16 women; median age, 40.3; SD, 10.6; age range, 25–55), with a post injury duration of six to 84 months (mean, 26.2; SD, 23.6), participated in our study. Patients had either WAD II (neck complaints and musculoskeletal signs) or WAD III (neck complaints and neurological sign(s)). None of the patients presented with peripheral or central nervous system disorders, inner ear pathology, or dizziness before the injury, and no head trauma or loss of consciousness occurred during the accident.

Control subjects

A sample of convenience consisted of 23 healthy individuals (seven men and 16 women) aged 18–54 years (mean, 34.2; SD, 13.7). None presented with the abovementioned disorders.

All participants signed an informed consent approved by the institutional review boards of Tel-Aviv University and Meir General Hospital, Israel.

Instrumentation

Eye movement measurements were conducted using the Chart® ENG for Windows® Eye Movement Test System (ICS Medical Corporation, Schaumburg, Illinois, USA). Tests were performed in a quiet, darkened room, with the patient seated using a specially constructed swivel chair.

Participants were tested in the following order: (1) smooth pursuit tracking, with the red light spot target moving horizontally at an average velocity of 0.75 m/sec spanning an arc of 16.7° to the left and right of the midline. (2) Saccades, with stimulus light target switched on pseudo-randomly on the light bar to the right and left in amplitudes of 5–30°, in steps of 5°. Each of these eye movement patterns was tested in three neck positions using the same order: neutral and 30° of trunk right/left rotation relative to the stationary head. Neck torsion was

Abbreviations: CV, coefficient of variation; EOG, electro-oculography; L, left; R, right; SPNT, smooth pursuit neck torsion; SPVG, smooth pursuit velocity gain; WAD, whiplash associated disorders
was achieved by turning the subject’s body on the chair while the head was supported at midline by the examiner, creating a relative 30° left/right neck torsion, respectively. This amount of rotation was used because it was the maximal range tolerated by all patients. All tests were conducted by the same examiner (TP). Participants were instructed and encouraged to track the moving targets as precisely as possible.

Outcome measures

- Right/left SPVG in the three neck positions. The velocity gain is the ratio: (eyes peak velocity)/(target velocity). The mean SPVG was calculated based on all accepted gains for the specific situation; namely, neck position and tracking to the right or left. The difference between the mean gain in neutral and the mean gain in right (R) + left (L) neck torsion (SPNTdiff) was calculated as follows:
  
  \[ SPNT\text{diff} = (\text{neutral position (gain R + gain L)/2}) - (\text{right torsion (gain R + gain L) + left torsion (gain R + gain L)}/4). \]

- Saccades: mean right/left peak velocities for small (5–19°) and large (20–30°) amplitudes and mean right/left accuracy and latency from both amplitudes pooled together.

All outcome parameters were collected in the three neck positions.

Using SAS version 6.1 (SAS institute, Cary, New Carolina, USA), a mixed model approach (PROC MIXED) was applied to analyse differences between groups (WAD versus control) and within groups (three neck positions), with age, sex, and stimulus direction (rightward or leftward) as covariates.

RESULTS

Table 1 presents the outcome values of the main findings: mean values of the SPVG and their corresponding coefficients of variation (CV = (SD/mean) × 100) and saccadic latencies.

A significant difference \( (F_{1,86} = 5.66; p = 0.01) \) was found between the groups, with SPVG higher by 0.058 in the controls. Age or sex had no effect. Similarly, in terms of consistency of performance, there was a significant difference between the groups: the mean CV of the controls was 5.4% between the groups; the mean CV of the controls was 5.4% less than that of the patients \( (F_{1,76} = 13.36; p = 0.0005) \).

The mean SPNTdiff values did not distinguish between the groups: 0.035 (SD, 0.097) and 0.026 (SD, 0.125) in the control and WAD groups, respectively. Figure 1 depicts the cumulative frequency of the cases in both groups as a function of SPNTdiff. Clearly, there was an almost perfect overlap, ruling out any differentiating power attributable to the SPNTdiff.

No significant differences were revealed between saccadic peak velocities with respect to directions, neck positions, amplitude, or groups. In addition, no significant differences were found between or within groups regarding saccadic accuracy. Table 1 indicates that patients had a higher latency score \( (21.9 \text{ ms}; F_{1,47} = 12.45; p = 0.001) \). However, no differences were noted with respect to neck positions.

DISCUSSION

Two principal results emerge from our present study. First, neck torsions of 30° did not affect eye movement performance in either group. Second, patients with WAD had significantly lower SPVG and prolonged saccadic latency.

The first result does not agree with previous findings.\(^10\)\(^11\) To account for the discrepancy, it should be noted that in our present study, the neutral position SPVG in the patients was already significantly smaller than that of the controls: 0.78 versus 0.84, respectively. Moreover, the corresponding slight (non-significant) reduction in SPVG that occurred during neck torsion (0.75 versus 0.81, respectively) was proportionally identical in both groups, and could be attributed to torsion, fatigue, or decreased compliance. We speculate that differences in symptom severity could partly account for the observed variations between the two studies, whereas age range differences would affect the results only marginally.\(^14\) This speculation is supported by the fact that our patients could not reach or maintain 45° of neck torsion because of pain or discomfort. Thus, 30° of rotation was used. Although this extent of rotation may not have been as provocative as 45°, it should be noted that 45° was not uniformly applied in the earlier study—the authors emphasised that they used “a maximum of 45°, or some angle which did not increase pain, stress, and/or other discomfort”\(^11\). It is also possible that the prolonged restrictions in the patients’ cervical mobility, as indicated by measurements not reported in our current study, contributed to an initial ocular–motor impairment. This assumption is supported by research indicating that restraining cervical motion compromised voluntary saccade velocity and SPVG.\(^17\)

Regarding saccades, our present findings show no effect of neck torsion on velocity, accuracy, or latency in either group, indicating that there was no cervical influence on performance and no lack of motivation or reduced voluntary effort during the tests.

However, latency was the only saccadic parameter that significantly differentiated between the groups, being unaffected by neck torsion but prolonged in the patients. We would like to make two comments in this regard. First, the

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**Table 1** | SPVGs, corresponding CVs, and saccadic latencies in both groups and in the three neck test positions (right and left stimuli pooled together)

<table>
<thead>
<tr>
<th></th>
<th>Neutral position</th>
<th>30° right torsion</th>
<th>30° left torsion</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAD SPVG</td>
<td>0.79 (0.11)</td>
<td>0.74 (0.10)</td>
<td>0.75 (0.01)</td>
</tr>
<tr>
<td></td>
<td>17.04 (10.00)*</td>
<td>17.38 (9.53)</td>
<td>16.32 (7.54)</td>
</tr>
<tr>
<td>Control SPVG</td>
<td>0.86 (0.01)*</td>
<td>0.82 (0.14)</td>
<td>0.80 (0.01)</td>
</tr>
<tr>
<td></td>
<td>10.76 (5.63)%</td>
<td>11.87 (4.52)</td>
<td>10.45 (3.70)</td>
</tr>
<tr>
<td>WAD latency</td>
<td>229.80 (45.60)</td>
<td>212.00 (35.02)</td>
<td>226.41 (57.35)</td>
</tr>
<tr>
<td>Control latency</td>
<td>195.90 (23.30)</td>
<td>190.01 (28.32)</td>
<td>187.08 (22.82)</td>
</tr>
</tbody>
</table>

All scores were rounded off to the second decimal point.

*SPVG (mean (SD)); CV (coefficient of variation %); saccadic latencies (ms).
recorded difference, although significant, may not have substantial clinical relevance. Second, saccadic latencies are affected by the state of attention; patients with chronic WAD suffer from attention impairments expressed by longer response time, and in the absence of morphological brain changes, it is more likely that the severity of pain and suffering in our patients could account for the increase in saccade latency.

Within the context of symptom validation, the introduction of a consistency parameter—the CV—is of particular interest. As far as we are aware, this is the first study to refer to the consistency of EOG related parameters. The mean control group CV scores of the SPVG (10.5–11.8%) were well within the acceptable margins of other biological phenomena, particularly when the complex nature of ocular–motor control is taken into account. The significant increase in the patients’ CV scores of the SPVG (16.3–17.4%) probably results from the existence of pathology or pain. However, the large overlap of CV scores means that it does not make an efficient differentiator.

In conclusion, although unaffected by neck torsion, SPVG reduction and saccade latency prolongation vary in patients with chronic WAD, reflecting pain related effects on oculo–motor performance.

ACKNOWLEDGEMENTS
The authors extend their sincere appreciation to the Research Fund affiliated to the Consortium of Israel Insurance Companies for supporting this research. We also wish to thank Mrs I Peer for her assistance in the ENG laboratory.

Authors’ affiliations
T Prushansky, Z Dvir, Department of Physical Therapy, Sackler Faculty of Medicine, Tel Aviv University, Israel 69978
E Pevzner, Spinal Care Unit, Meir General Hospital, Israel 44409
C R Gordon, Department of Neurology, Meir General Hospital and Sackler Faculty of Medicine, Tel Aviv University

Correspondence to: Ms T Prushansky, Department of Physical Therapy, Sackler Faculty of Medicine, Tel Aviv University, Israel 69978; zdvir@post.tau.ac.il

Received 29 October 2003

Accepted in revised form 6 February 2004

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Electro-oculographic measures in patients with chronic whiplash and healthy subjects: a comparative study
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J Neurol Neurosurg Psychiatry 2004 75: 1642-1644
doi: 10.1136/jnnp.2003.031278

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