



The Discrepancy between Subjective and Objective Measures of Convergence Insufficiency in Whiplash-Associated Disorder versus Control Participants

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Purpose: Motor vehicle accidents (MVAs) are a pandemic associated with human suffering and a burden to national economies. Whiplash-associated disorders (WADs) after MVAs are associated commonly with disability claims, many of which are related to vision. Convergence insufficiency (CI) leads to visual disability associated with symptoms of ocular discomfort. We examined the incidence of symptoms and findings consistent with CI in a cohort of patients after MVA-related WAD compared with age-matched control participants.

Design: Prospective cohort study.

Participants: Patients with WAD after MVA were recruited from the Orthopedic Emergency Department between July 2014 and March 2017. Control participants were recruited among hospital personnel and relatives of WAD patients.

Methods: The Convergence Insufficiency Symptom Survey (CISS) questionnaire was completed by each participant, followed by a detailed visual examination including measurements of distance and near best-corrected Snellen visual acuity, distance and near cover test, Randot stereopsis, Maddox distance and Maddox-Thorington near heterophoria, near point of convergence, base-out step fusional reserves, and amplitude of accommodation using the push-away method.

Main Outcome Measures: The CISS score and binocular measure findings of CI were recorded and analyzed using Student's *t* test, the chi-square test, and multiple logistic regression adjusted for age and gender.

Results: A pathologic CISS score of 16 or more occurred in 26 of 57 WAD patients (45.6%) compared with 6 of 39 control participants (15.4%; $P = 0.002$). Absolute CISS score was higher in the WAD group compared with the control group (15.3 ± 10.0 vs. 7.7 ± 7.7 ; $P < 0.001$). Findings consistent with CI occurred in 7.0% of WAD patients and 7.7% of control participants ($P = 0.90$).

Conclusions: Visual symptoms suggestive of CI were reported more frequently among WAD patients compared with control participants, yet the incidence of examination findings indicating weakness of convergence was not increased. The discrepancy between subjective and objective measures of CI in WAD patients versus control participants stresses the importance of training healthcare personnel to assess disability using objective, validated standards of examination. *Ophthalmology* 2017;■:1–5 © 2017 by the American Academy of Ophthalmology



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Motor vehicle accidents (MVAs) are a pandemic entailing both human suffering and a burden to national economies. In 2016, an estimated 24% of lost workplace productivity in the United States resulted from MVAs.¹ The estimated 2010 comprehensive cost of MVAs in the United States was \$836 billion.¹ In the United Kingdom, personal injury claims from MVAs are rising, with almost 80% of claims accounted for by whiplash and soft tissue injuries. The authors noted that although the annual number of accidents on British roads decreased 30% between 2005 and 2013, the number of settled personal injury claims from road traffic accidents increased by 62%,² some even occurring as a so-called crash-for-cash phenomenon.

Disability outcomes after MVAs and whiplash-associated disorder (WAD) have been linked to the possibility of compensation.^{3,4} One suggestion for decreasing the load on the United Kingdom economy is to implement formal accreditation of medical practitioners who diagnose whiplash and soft tissue injuries and to train medical personnel with specific qualifications in bodily injury diagnosis.²

Among WAD patients, an estimated 50% report problems with vision, including difficulty reading, visual fatigue, and eye strain.⁵ In an effort to produce objective standards of examination for future research on the implications of neck injury, important progress made by a group from The Netherlands linked abnormalities in the cervico-ocular

reflex, the vestibule-ocular reflex, and in smooth pursuit to WAD.^{6–8} Measures of eye movements such as cervico-ocular reflex, vestibule-ocular reflex, and smooth pursuit abnormalities have been linked robustly to WAD,^{6–8} but cannot be used to measure the clinical syndrome of convergence insufficiency (CI).

The syndrome of CI is characterized by a decreased ability to converge the eyes and maintain binocular fusion while focusing on a near target. Convergence insufficiency is a clinical entity that has been linked to loss of productivity at the workplace and reduced quality of life.^{9,10} As such, it is a recognized and distinct form of visual disability worldwide. Not all patients who report eye strain, diplopia, or fatigue after short periods of reading have measurable findings consistent with CI.

Convergence insufficiency is a common disorder not limited to patients after WAD or MVA injuries. Its reported prevalence in the general population is 8.3%.¹¹ The aim of this study was to examine whether the incidence of CI is increased after WAD and to compare the incidence of CI-related symptoms, using a validated questionnaire,¹² with the incidence of objective clinical signs.

Methods

All data for this prospective cohort study were collected and analyzed in accordance with the policies and procedures of the institutional review board of the Rabin Medical Center and the tenets set forth in the Declaration of Helsinki. Participants were recruited after obtaining written informed consent.

Study Participants

After institutional review board approval, participants were recruited from the Orthopedic Emergency Department between July 2014 and March 2017. Hospital employees and companions accompanying patients were recruited as control participants. Patients with WAD were included if they had sustained a neck injury resulting from a rapid back-and-forth movement of the neck during an MVA. Exclusion criteria included concurrent neurologic injuries or pre-existing lack of binocular vision (amblyopia, history or findings of strabismus, or ophthalmic disease precluding binocular vision). Control participants were included after excluding those with pre-existing lack of binocular vision or neurologic illness.

Orthopedic Assessment

Patients were examined by an orthopedic surgeon in the Orthopedic Emergency Department. Additional imaging studies were conducted based on clinical examination findings, in accordance with the National Emergency X-Radiography Utilization Study (NEXUS) Low-Risk Criteria.^{13,14} Patients then were classified according to the Modified Quebec Task Force Classification on Whiplash-Associated Disorders (Table 1).¹⁵

Visual Assessment

Visual examination was performed by licensed optometrists and included measurements of distance and near Snellen visual acuity (best corrected when necessary), distance and near cover test, Randot stereopsis, Maddox distance and Maddox-Thorington near

Table 1. Distribution of Whiplash Severity in the Whiplash Group Based on the Quebec Task Force Grading Scale

Grade	No. (%)	Description
0	7 (12.3)	Whiplash injury but no pain, symptoms, or signs
1	46 (80.7)	Delayed neck pain, minor stiffness, nonfocal tenderness only, no physical signs
2	4 (7.0)	Early onset of neck pain, focal neck tenderness, spasm, stiffness, radiating symptoms
3	0 (0)	Early onset of neck pain, focal neck tenderness, spasm, stiffness, radiating symptoms and signs of neurologic deficit
4	0 (0)	Neck complaint (grade 2 or 3 above) and fracture dislocation

heterophoria, near point of convergence (measured using an accommodative target in those without presbyopia and a penlight in those with presbyopia), and base-out (BO) step fusional reserves and amplitude of accommodation using the push-away method. Please see the Appendix (available at www.aaojournal.org) for a detailed description of binocular vision tests used. Participants in the WAD group were evaluated within a median of 15 days after the MVA (21.4±21.8 days). For subjective patient-reported symptoms, each recruited patient also filled out the Convergence Insufficiency Symptoms Survey (CISS) questionnaire.¹²

For each participant, a record was made regarding whether he or she showed findings consistent with CI and if subjective symptoms of CI were 16 points or higher on the CISS.^{12,16,17} Criteria for presence of findings consistent with CI were based on Convergence Insufficiency Treatment Trial criteria¹⁸ and were discussed further with M. Scheiman (personal correspondence). These findings included exophoria at near at least 4 prism diopters (PD) more than the exophoria at distance not meeting Sheard's criterion (BO break less than twice the near exophoria value) or BO break of 15 PD or more or BO blur of 15 PD or more, near point of convergence of 5 cm or more, and a CISS (16-item questionnaire) score of 16 or more.

Power Analysis

Assuming a prevalence of adult-onset convergence 10%,¹⁹ an incidence of posttraumatic CI of 42%,⁵ a power of 0.80, and an α of 0.05, we calculated that at least 30 participants would be required in each group.

Statistical Analysis

Statistical analysis of results was performed with the Minitab software, version 17 (Minitab, Inc., State College, PA). For the analysis of continuous and categorical data, Student *t* tests and chi-square tests were performed with the primary outcomes as dependent variables and with study group, age, and gender as the independent variables. Results were expressed as mean ± standard deviation or number (%). In all analyses, a 2-sided *P* value of less than 0.05 was considered statistically significant. Figures depicting the results were rendered from a second analysis using R software version 3.4.1 (CRAN.r.project.org version 3.1.2).

Results

Overall, 96 patients were included in this cohort: 59.4% in the WAD group (*n* = 57) and 40.6% in the control group (*n* = 39).

Table 2. Baseline Characteristics of Patients in the Whiplash and Control Groups

Parameter	Whiplash Group (n = 57)	Control Group (n = 39)	P Value*
Age (yrs)	37.2±11.4	39.2±11.7	0.41
Gender (% male)	43.9	33.3	0.30
Average distance binocular visual acuity (Snellen decimal)	0.95±0.11	0.99±0.03	0.21 [†]
Average near binocular visual acuity (Snellen decimal)	0.92±0.11	0.99±0.04	0.007 [†]
Stereopsis (arc sec)	66±71	80±112	0.21 [†]
Distance heterophoria (alignment, PD)	0.19±2.32 EP	0.31±2.32 XP	0.41 [†]
Near heterophoria (alignment, PD)	1.21±3.70 XP	3.21±4.67 XP	0.03
Near point of convergence break (cm)	3.84±4.49	4.85±5.16	0.38 [†]
Near point of convergence recovery (cm)	4.24±6.53	7.38±8.01	0.72 [†]
Accommodative amplitude (D) [‡]	9.15±3.50	8.75±2.89	0.41 [†]

D = diopters; EP = esophoria; PD = prism diopters; XP = exophoria.

*Student *t* test used for continuous variables and chi-square test used for categorical variables.

[†]Mann–Whitney *U* test used for comparisons of data not distributed normally.

[‡]Amplitude of accommodation not measured in patients requiring reading glasses.

Table 2 depicts a comparison between the WAD and the control groups' baseline characteristics. The mean age of the participants was 38.0±11.5 years (range, 20–64 years), and 39.6% were men (n = 25). Briefly, there were no significant differences in terms of age ($P = 0.41$) or gender ($P = 0.30$) between the groups.

A pathologic CISS score of 16 or more occurred in 26 WAD patients (45.6%) as opposed to 6 control participants (15.3%). The absolute CISS score was significantly higher in the WAD group compared with the control group (15.3±10.0 vs. 7.7±7.7; $P < 0.001$), and a greater proportion of WAD patients had a pathologic CISS score (45.6% vs. 15.4%; $P = 0.002$; Fig 1; Table 3).

As opposed to subjective symptoms, a similar proportion of participants met the criteria for CI findings (7.0% vs. 7.7%; $P = 0.90$) in both the WAD and the control groups. Assuming a difference in proportions of participants meeting the criteria for CI of 0.7%, we calculated at a power of 0.8 that more than 9000 patients and 20000 control participants would be required in each group for this difference to reach the 0.05 significance level. After stratification, patients with higher grades of WAD (WAD grade ≥ 1) met CI criteria at a similar rate as healthy control participants and those with WAD grade 0 (6.25% vs. 8.7%; $P = 0.65$). However, the CISS score of patients with WAD grade of 1 or more was 15.48±9.97 versus 8.50±8.34 in control participants and patients with WAD grade 0 ($P < 0.001$).

After adjusting for age and gender using multiple logistic regression analysis, WAD remained associated significantly with a higher CISS score ($R^2 = 15.7$; $P < 0.001$) and a pathologic CISS score of 16 or more (odds ratio, 5.67; $P = 0.001$). However, after the same age and gender adjustment, WAD was not associated significantly with increased incidence of findings consistent with CI (odds ratio, 0.99; $P = 0.99$).

Discussion

An estimated 50% of patients with WAD report problems with vision, including difficulty reading and eye strain,⁵ suggestive of CI, a clinical disorder of binocular vision affecting productivity and leading to a decreased quality of life.¹⁸ In this study, although eye symptoms suggestive of CI (CISS score, ≥ 16) were more common in patients with WAD (45.6% vs. 15.4%; $P = 0.002$), measurable findings consistent with CI were not more frequent in the MVA group with WAD compared with control

participants (7.0% vs. 7.7%; $P = 0.90$). This mismatch highlights the importance of the examiner's proficiency with the clinical evaluation of CI and the possibility of patient exaggeration for secondary gain. Prior studies have shown that patients claiming compensation have worse overall health outcomes than those who do not claim compensation.²⁰ We recommend that healthcare personnel examining patients after MVAs use validated criteria to distinguish between symptoms and measurable disability.

In the current study 7.7% of healthy control participants met the criteria for CI. The reported rates of CI in the general population vary greatly, from 2% to 33% depending on factors such as target population, diagnostic criteria, testing protocols, age, study settings, and sampling methods.¹⁹ Recently, Ostadimoghaddam et al¹⁹ reported the results of the first large cross-sectional population-based

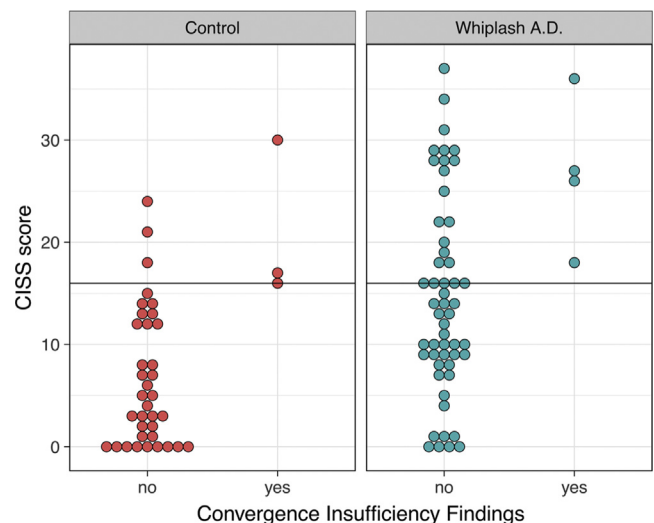


Figure 1. Graph showing that the whiplash-associated disorder (AD) and control groups were similar in terms of age ($P = 0.41$) and gender ($P = 0.30$). The Convergence Insufficiency Symptom Survey (CISS) score was significantly higher in the whiplash group than in the control group ($P < 0.001$).

Table 3. Results of Convergence Insufficiency Symptoms Score and Findings

	Whiplash Group (n = 57)	Control Group (n = 39)	P Value*
CI symptom score	15.3±10.0	7.7±7.7	<0.001 [†]
Pathological CI symptom score (≥16), %	45.6	15.4	0.002 [†]
Meeting criteria for CI findings, %	7.0	7.7	0.90

CI = convergence insufficiency.

*Student *t* test used for continuous variables and chi-square test used for categorical variables.

[†]Remained significant after adjusting for age and gender in multivariate analyses.

study investigating the prevalence of CI. They reported CI in 5.46% of participants from Northeast Iran with ages similar to those of participants in our study (mean, 30.5 years; range, 10–60 years).¹⁹ Two previous studies, carried out more than 2 decades ago, assessing the prevalence of CI focused on adults.^{21,22} Porcar and Martinez-Palomera²¹ reported a prevalence of 7.7% in young adults when requiring 4 diagnostic criteria, and Pickwell et al²² reported a prevalence of 14% in all adults when requiring 1 diagnostic criteria. Considering the diagnostic criteria and age of the study population in the current study, the prevalence of CI is similar to that of previous reports that studied populations of similar age using similar diagnostic criteria.^{19,21}

This study recruited 96 patients, meeting the initial number calculated to meet the power for analysis. A shortcoming is the small number of participants with high grades of WAD recruited to this study (only 3 participants had WAD grade of ≥2), reflecting the actual incidence of severe WAD after MVAs in the Orthopedic Emergency Department. Our tertiary referral center serves more metropolitan areas than highways; thus, it may be difficult to predict the actual incidence of CI in high-grade WAD. Future studies may investigate whether higher grades of WAD lead to more frequent CI. However, it is possible that higher grades of WAD are associated most commonly with neurologic injuries, an exclusion criterion of the current study. This study intentionally focused on CI among the most common disorders of the WAD, a population with frequent claims of visual disability. Another limitation of this study is the varied period by which participants were examined after the accident (21.1±21.8 days; median, 15 days).

Although CI is a listed form of disability worldwide and commonly is ascribed to WAD after MVAs, it is not unique to WAD, with an estimated incidence in the general population of approximately 8%.¹¹ In this study, designed to investigate whether the incidence of CI is increased in the setting of WAD, we found that although the incidence of visual symptoms was increased among WAD patients (a greater proportion of WAD patients had pathologic CISS results, 45.6% vs. 15.4%; $P = 0.002$), the number of patients meeting clinical criteria for measurable signs of

CI was not increased compared with control participants (7.0% vs. 7.7%; $P = 0.90$).

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Abbreviations and Acronyms:

BO = base-out; **CI** = convergence insufficiency; **CISS** = Convergence Insufficiency Symptom Survey; **MVA** = motor vehicle accident; **WAD** = whiplash-associated disorder.

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