IN-DEPTH STUDY OF WHIPLASH ASSOCIATED DISORDERS IN FRONTAL IMPACTS: INFLUENCING FACTORS AND CONSEQUENCES

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ABSTRACT

This multidisciplinary in-depth investigation of accidents using 24 occupants with neck symptoms shows the complexity of Whiplash Associated Disorders (WAD) in frontal impacts with respect to factors that influence occurrence as well as duration of symptoms. Two cases of unbelted occupants with a neck compression mechanism far from conventional "whiplash" motion were found. Posture related, as well as physical and psychosocial factors such as strong negative reactions, bad prognosis expectation and stressed daily activities influenced the duration of symptoms. Occupant characteristics as well as sitting posture and behaviour at the time of impact are important factors when analysing and understanding WAD.

Key words: whiplash, frontal impacts, neck symptoms, duration

WHIPLASH ASSOCIATED DISORDERS (WAD) are among the most frequent injury types resulting from car impacts (Norin et al. 1997). WAD occur in all types of accident. For frontal impacts, frequencies of 12% to 24% are reported in the literature (Morris et al. 1996, Temming and Zobel 1998, Jakobsson et al. 2000). According to the definition of WAD by the Quebec task force (Spitzer et al. 1995), complaints of neck pain, stiffness and tenderness with or without musculoskeletal or neurological signs are included. Certain symptoms and disorders such as deafness, dizziness, tinnitus, headache, memory loss, dysphagia and temporomandibular joint disorders may also appear.

In order to introduce preventive measures towards WAD in frontal impacts, an understanding of the mechanisms behind the symptoms' occurrence is a necessary first step and a complement to statistical analyses. The objective of this study is to identify influencing factors with respect to the occurrence and consequences of WAD in frontal impacts. This is done by analysing a subset of 24 occupants, all reporting neck complaints following a car accident.

METHOD

DATA COLLECTION: Car occupants alleging neck symptoms after a frontal crash in a Volvo vehicle were invited to join the study at the Traffic Injury Register in Göteborg, Sweden. Most of the cases were found through the hospitals' emergency care departments in Göteborg. Some were found via Volvo's accident research team or through the Volvia insurance company. The study was approved by the Ethic Committee of Göteborg University and informed consents were obtained in all cases. The occupants were thoroughly examined by a physiotherapist within 3 weeks, 3 months and 1 year after the accident. All the cars and accident circumstances were examined by Volvo's accident research team. A theoretical reconstruction was made in each case, from where for example the impact severity was estimated. In one car there was an onboard crash recorder. A total of 24 occupants in 16 frontal impacts were included. The cases represent drivers, front and rear seat passengers in several different

Volvo models, with year models ranging from 1981 to 2000. Even though there are a limited number of participants, there is no systematic selection of the individuals.

DATA CONTENT: In each of the three examinations, details regarding pain level, pain location and cervical range of motion in flexion/extension and right/left lateral flexion and rotation, together with neurological symptoms in the arms (at rest and during compression and traction of the cervicobrachial nerve roots and plexus) were documented. The pain level was estimated with the Visual Analogue Scale (VAS) (Carlsson 1983) where VAS 0.0 is no pain and VAS 10.0 is the worst imaginable pain.

The occupant's sitting posture at the time of impact was reconstructed and documented with the occupant in the actual vehicle, or one identical to it, within three weeks of the accident. In all cases except two, initial x-ray images were taken of the neck. Questionnaires on general health issues and specific symptoms related to neck disorders were answered initially and 1 year after the accident. Several psychometric questionnaires were also included in the study. In Appendix 1, the details of each case regarding car model, impact situation and severity, safety systems and the occupant's sitting posture, gender and age are found. The cases are identified by a combination of a letter and a figure: the letter being the car and the figure the seating position of the occupant (1=driver, 2=front seat passenger, 3=left rear seat passenger, 5=right rear seat passenger).

ANALYSIS METHOD: All cases have been analysed by a multidisciplinary group of car crash analysts, orthopaedic, neurological and radiology experts, physiotherapists and biomechanical specialists. Each case was analysed some months after the accident and when all the data had been collected. The analyses included the impact direction, the change of velocity (deltaV, ISO 1998), the sitting posture, the trajectory of the occupant relative to the car, the possible occupant loading mechanisms with regard to the safety systems and the occupant's own protective reactions. It also included the possible causes of the neck symptoms, and influencing factors with regard to previous neck problems or neck problems due to other causes after the accident which might influence the character, intensity, and duration of the symptoms.

An overall symptom intensity grouping (SI) was created based on the questionnaire and examination data. The symptom intensity included the self-reported maximum and minimum pain in the last week, the actual pain before the examination and during all neck motions in the examination, together with cervical ranges of motion, neurological symptoms and the extension and degree of tenderness in the neck-shoulder area. The levels of the SI were 0=no symptoms, 1=minor intense symptoms, 2=moderate intense symptoms, 3=intense symptoms. A typical individual graded as SI 1 would have some neck related symptoms, but not constantly. The occupant would consider the symptoms as not too bothersome. An individual graded as SI 3 would have constant pain at more than VAS 5: the pain and restricted motion would considerably affect day-to-day life. Pain locations in motion tests: active as well as isometric in the neutral position (flexion, extension, right/left lateral flexion and rotation, protraction and retraction), tenderness points and pain localisation, together with arm symptoms if any, were used when defining primary side of symptoms (PSS). PSS could be left, right, central or symmetric. The symptom intensity and the primary side of symptoms as well as WAD for each occupant can be seen in Appendix 1.

RESULTS

SYMPTOM CATEGORISATION: The symptoms of the occupants were categorised according to the Quebec classification of WAD (Spitzer et al 1995). Of a total of 24, as many as 18 were graded as WAD 2 in the primary examination. These 18 occupants had very different neck symptom intensities and thus their daily lives were affected very differently. Three of the occupants (cases A1, J1 and K5) did not fit into any of the WAD groups at the primary examination, since they had no pain but did have clinical findings (such as tenderness). Since the WAD classification does not give information about localisation and intensity of the symptoms, the WAD classification was found to be not sensitive enough for the purposes of this study. In the analyses below, symptom intensity (SI) and primary side of symptom (PSS) were mainly used when categorising symptoms.

GENERAL OVERVIEW OF INFLUENCE ON INITIAL SYMPTOMS

Impact severity: When plotting deltaV versus initial symptom intensity, no clear correlation can be seen, Fig. 1. The span of deltaV in this subset varies from below 5 km/h to just above 20 km/h and moderate intense symptoms can be seen throughout the whole severity interval.

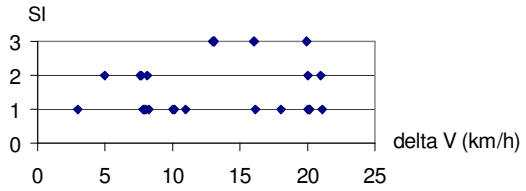

Fig. 1 - DeltaV (km/h) versus initial symptom intensity (SI).

Occupant characteristics: All the different initial symptom intensity levels can be found for both women and men, see Appendix 1. Regarding occupant stature versus initial symptom intensity (SI), a slight trend towards higher SI for taller occupants can be seen, Fig 2a. It is difficult to draw conclusions when comparing occupant weight versus initial SI, see Fig 2b.

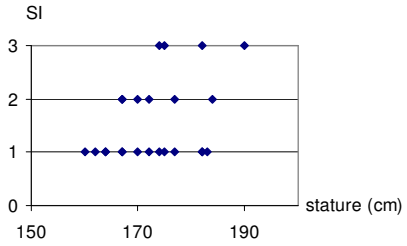

Fig. 2a - Occupant stature versus initial symptom intensity (SI).

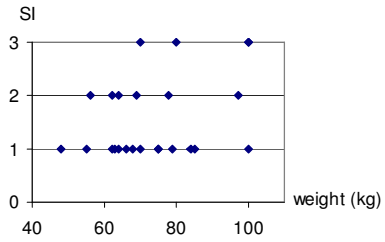

Fig. 2b - Occupant weight versus initial symptom intensity (SI).

The women generally had a slimmer neck, although all initial neck symptom intensity levels could be found throughout the spectrum of neck circumferences, irrespective of gender. Minor or moderate X-ray findings, indicating degenerative changes of the intervertebral discs and/or facet joints, were noted in 10 cases, with no correlation between degenerative changes and initial SI.

Prior neck symptoms: The distribution of symptom intensity as a function of neck symptoms prior to the accident can be seen in Table 1.

Table 1 - Initial symptom intensity (SI) versus prior neck symptoms.

	SI 1	SI 2	SI 3
Prior neck symptoms	8	3	
No prior neck symptoms	6	2	4

IN-DEPTH ANALYSIS BASED ON PROBABLE OCCUPANT LOADING: Several occupant-loading mechanisms were identified. The kinematics were categorised based on the possible motion of the occupants due to where the forces were mainly transferred to the body. Half of the occupants were restrained by the seat belt only, thus restricting the upper body's forward movement by resistance to either the left or right shoulder. In this group, the neck was exposed to a possible protraction and then flexion motion with more or less lateral flexion influence depending on the impact direction and sitting posture. Two of the rear seat passengers leaned forward, arms covering their heads, in a protective position. The kinematics of these occupants would be quite different to those sitting upright in the seat. The neck motion mechanism would probably be more of a tension mechanism in combination with less flexion motion than the upright sitting posture. Seven occupants straightened their arms forward, getting load through the arms, which probably affected the neck motion. Three of the drivers were restricted by both airbag and belt (incl. pretensioners). The kinematics and neck motion mechanisms are then difficult to determine since they are dependent on the timing of the event.

It is possible that the neck flexion motion could be reduced. The two drivers not wearing seat belts moved upwards and struck their heads on the windscreen (case N1) or sun shield (case O1). These two had more of a compression neck load, far from the traditional "whiplash" type of motion.

Even though there were different occupant kinematics and neck motions, all the occupants sustained symptoms agreeing with the definition of whiplash associated disorders (Spitzer et al, 1995). When categorising the occupants within the different occupant loading groups, the distribution of initial neck symptom intensity in Table 2 could be seen.

Table 2 - Initial symptom intensity (SI) versus occupant loading groups.

	SI 1	SI 2	SI 3
Belt load only	10	1	1
Arm res. only		1	
Belt load + arm res.	2	3	1
Head impact			2
Airbag and belt	2	1	

Although only dealing with a few cases, Table 2 gives an indication that the head impact mechanism might result in more intense symptoms. The two cases will be presented in detail below.

Unbelted head impact mechanism: Cases N1 (Fig. 3a) and O1 (Fig. 3b) were both unbelted drivers. They both struck their heads and in case N1 there was clear evidence of head impact to the windscreen.

Fig. 3a - Photo of car in case N1, note the windscreen head indentation.

Fig. 3b - Photo of car in case O1.

The Volvo 445 in case N1 (Fig. 3a) was forced to give way to the right in a left hand turn and went off the road, impacting a tree. The deltaV was estimated to be 16-20 km/h. The unbelted 45-year-old man (190 cm, 100 kg) impacted his head on the windscreen and chin and mouth on the steering wheel. He reported periods of unconsciousness over 15-30 minutes. He had a history of knee and shoulder problems as well as tinnitus in left ear, but no prior neck or back complaints. He was brought to the hospital the same day but did not notice any neck pain then. The following morning he returned to the hospital with pain on the left side of his neck. At the primary physiotherapist examination, 20 days after the accident, he had extensive aching neck pain and pain in the suboccipital area. His pain estimation, according to VAS, was 3.6 at the time of examination and between 2.9 and 8.5 during the last week. He had pain on the left side of the neck in flexion and extension motions with a normal range of motion (50-60 degrees), contra-lateral pain in lateral flexion, sensory disturbances at brachial nerve traction tests on both sides and tender points centrally and to the left of the neck. At the second examination, three months after the accident, he reported daily neckache and headache and occasional numbness in his left arm, although no arm symptoms during the nerve provocation tests. He experienced less pain during motion tests, except during rotation to the left, which caused suboccipital pain. At the one-year follow-up he had no pain at rest, but frequent pain and tenderness in the occipital area and occasionally in the forehead. His motion pain pattern was almost identical to before. At all three examinations he was graded WAD 2 and due to the intense and initially continuous symptoms, his neck symptoms were grouped in this analysis as SI 3 primarily and SI 2 one year after the accident. His earlier pain history may have some influence on the one-year outcome, it is also believed that his concern and initial negative prognostic expectations were influential.

The Volvo S40 in case O1 (Fig. 3b) was unable to stop at a T-junction due to slippery road conditions. The car impacted a brick wall with an estimated deltaV of 11-15 km/h. The 42-year-old male driver (182 cm, 100 kg) was not wearing a seat belt, but was to some extent restrained by the airbag. He sustained a laceration on his scalp, probably from the sun shield. He visited the emergency

department for neck pain and received a neck collar. At the primary examination, 19 days after the accident, he experienced intense and continuous pain and fatigue in the neck, with VAS ranging from 3.9-8.5 during the last week. The pain was located to the left in the neck and shoulder, aggravating during all neck motions at the examination. He had a very restricted cervical range of motion and was found to have a C6-rhitzopathy, classifying him as WAD 3. Initial x-ray images showed some degenerative changes to the discs and facet joints below C5, predominantly on the left side. After three months, he had somewhat less pain in the neck, though left arm symptoms as well as minor headache. The neck motion pain was located on the left side, irrespective of the type of motion. The range of motion was to some extent improved. He was unwilling to attend the one year follow-up, but reported residual symptoms and had been referred to the neurosurgery department for a disc herniation at the C5-6 level.

Arm resistance influence: Compared to belt load only mechanisms, the cases with arm resistance influence showed a greater representation of symmetrical neck symptoms (pain on both sides), see Table 3. All injured occupants with arm resistance, except case M1, reported symmetrical symptom pattern directly after the impact and showed symmetrical symptoms in the primary examination.

Table 3 - Initial primary symptom side (PSS) versus body load mechanism.

	left	symmetric	right
Belt load only	2	1	9
Arm res. only		1	
Belt load + arm res.		5	1
Head impact	2		
Airbag and belt	2		1

Occupants with arm resistance mechanism were found to be drivers, Fig. 4a, one front seat passenger, Fig. 4b and one unbelted rear seat passenger managing to retain his motion by his arms only (case M5).

Fig. 4a - Driver with arm resistance (case C1)

Fig. 4b - Front seat passenger with arm resistance (case C2)

The 20-year-old man in case C1 (Fig. 4a) was the driver of a Volvo 240, impacting the rear of a Seat Ibiza. He pushed himself towards the seat during the impact with straight arms, probably transferring a substantial part of the body load (estimated deltaV of 6-10 km/h) through his arms. He reported symptoms the day after the accident, which he could clearly differentiate from his prior neck symptoms from a previous accident. The symptoms at the primary examination were symmetrically distributed over the neck and shoulders, mainly in the form of stiffness. Three months later he had less dispersed pain, mainly tenderness and stiffness in the neck. One year after the accident he had no neck problems, either from the previous accident or the in question. The 20-year-old front seat passenger in the same vehicle (case C2, Fig. 4b) remembered putting his arms up in front of him against the dashboard. He immediately suffered from symmetrical pain in the lower part of the neck, reporting maximum VAS of 6.0 and minimum 0 over the following weeks. At the primary examination he reported VAS 0.8 and the pattern of symptoms was very symmetrical. He recovered within one month and had no neck symptoms at the second and third examination.

Three other restrained drivers (D1, E1 and Q1) and one unrestrained rear seat passenger (M5) with arm resistance showed similar symmetrical symptom patterns. The 34-year-old driver in D1 experienced stiffness and tightness as a result of the very light impact (deltaV less than 5 km/h). The symptoms were classified as being of minor intensity and since the findings (mainly palpation sensations) at the examination were recognised from prior to the impact, she was initially classified as WAD 1. After two weeks she had recovered. The 23-year-old woman in E1 was driving a Volvo 440 and impacted a Volvo 760 at an estimated impact severity of almost 20 km/h deltaV. She had no prior

neck problems and immediately experienced headache, neck and back pain following the impact. At the primary examination she reported actual pain corresponding to VAS 4.4 and during the previous week between 1.1 and 6.6. The palpation sensation was symmetrical and rotation and protraction/retraction led to aggravating symmetric pain above all in the occipital area. Three months later, she had less pain, but still ached in the occipital area occasionally and tenderness was found during examination. One year after the accident she had daily head and neck pain of VAS 5-6. The findings were classified as WAD 2 at all three examinations. Due to the continuous and sometimes very high pain intensity the first time after the impact, she was judged to have SI 3 primarily, and S1 2 after a year, due to the pain-free periods. The 33-year-old female driver of a Volvo 850 (Q1) impacted the rear of a Citroen with a deltaV of approximately 5 km/h. She pushed herself against the seat and was very tensed. Initially she ached in the lumbar region, but after a few days experienced neck pain and dizziness. At the primary examination she had symmetrical pain during all motions, reporting VAS 6.7. After three months she had an unchanged pain level and felt pain during all motions. One year after the accident she reported mainly headache, which she had had occasionally prior to the accident, but it was now more frequent. She reported no pain when attending the examination, but she experienced VAS 8 in extension motion as well as pain when rotating left and was also very tender. She recognised many of the symptoms from prior to the accident and related them to her active and stressful lifestyle, but they had increased due to the accident.

The unrestrained 25-year-old rear seat passenger (M5) restrained himself with his arms and knees against the back of the front seat when the Volvo 740 impacted the rear of a Volvo V40 at deltaV 6-10 km/h. He experienced stiffness in his neck and shoulders after a few hours. At the primary examination he had continuous pain (VAS 2.4-5.1), especially at the level of C7 with a symmetrical distribution. He was classified as WAD 2 and SI 2 both initially and after one year. The restrained 26-year-old driver of the Volvo 744 (M1) also restrained himself with his arms. In contrast to the other occupant with arm resistance, he had a clear right sided symptom pattern, e.g., pain in neck-shoulder angle at head rotation, irrespective of direction and pain as well as reduced sensibility in the same area. It can be anticipated that the right arm load was higher than that of the left arm since after 1 year he still had isolated right hand problems that he attributed to the accident.

Belt load: The distribution of primary symptom side (PSS) for the twelve occupants with mainly belt load holding is shown in Table 4.

Table 4 - Initial primary symptom side (PSS) versus shoulder belt side, for occupants with mainly belt load.

	Left	Symmetrical	right
Belt on left shoulder	2		5
Belt on right shoulder		1	4

It is interesting to note that there seems to be no dominant symptom side depending on shoulder belt position, see Table 4. A way to better understand the possible reasons for influencing factors is to take a more in-depth view of the pain location for different neck motions combined with occupant posture and belt loading during the impact. The symptom sides for the different neck motions during the primary examination are shown in Table 5.

Table 5 - Sitting posture, primary symptom side and symptom side for neck motions in flexion, extension, lateral flexion, rotation and arm symptom tests.
Occupants with belt load only.

Case	Belt side	Posture	PSS	Flex.	Extension	Lat. flex. left	Lat. flex. right	Rot. left	Rot. right	Arm sympt
A1	left	straight	r					r		
B1	left	head left	l	c	c	r	r	r	r	l
C5	right	leaning left	s	l		r		r	r	l
G2	right	straight	r	r		r		l		
H1	left	straight	r	s	c					
I1	left	straight	r							l+r
K2	right	head right	r	c	r	r	l	r	r	l+r
K5	right	forward	r							r
L1	left	straight	l	l	l	l	l	l	s	
K3	left	forward	r	r						
M2	right	head left	r							
P1	left	straight	r							r

Four of the occupants had right sided pain when rotating their head to either side. Cases B1, C5 and K2 had right sided pain when rotating both left and right. The four cases represent both left and right side shoulder belt loading as well as different occupant postures. They will be described in detail below to present the differences and similarities, showing the complexity of factors and resulting symptoms.

In case A1 a Volvo 745 with a 38-year-old driver, impacted a Citroen offset in a glance-off motion, resulting in somewhat leftward driver kinematics. The severity of the impact was estimated to a deltaV of 6-10 km/h. He felt stiffness in the right neck-shoulder angle the first evening that lasted a couple of days. At the primary examination, eight days after the impact, he had no symptoms from the accident. When rotating left, however, he felt some pain in the right neck-shoulder angle. The physiotherapist also found some tender points: one at the right neck-shoulder angle and the other on left shoulder. The latter was from prior to the impact. This case was difficult to WAD classify, because he had no pain, but there were some clinical findings. In case B1, the 34-year-old driver of a Volvo 850 sustained intensive neck symptoms after the car impacted the side of a Saab. Her kinematics were slightly to the left, striking her left shoulder against the door panel. Initially she felt stiffness, but the day after also experienced distributed pain, including arm symptoms. At the primary examination her pain was very intense: VAS 6.4. The week before the examination the VAS was never below 3.2. In both left and right rotation as well as right lateral flexion, pain was sensed in the right neck-shoulder angle. Although there were arm symptoms, this occupant did not have clear neurological signs, so she was classified as WAD 2. Due to the continuous and high symptom intensity, she was graded SI 3. After three months, her symptoms had clearly decreased. She reported no pain but did have occasional left arm problems and tender points and pain during neck motions. One year after the accident the problems had increased to a level almost equal to the initial level. She reported daily pain of VAS 3-4 distributed in the neck and had aggravated pain during flexion, left lateral flexion and left rotation. Pricking discomfort in her left arm and hand was noted, related to a trigger point in the left shoulder area and she was judged WAD 2 and SI 3. Case C5 was sitting in the right rear seat in the same car as C1 and C2. She leaned inwards at the time of impact. Initially, she reported only pain in the chest (probably due to the belt), but the day after experienced neck stiffness, especially at right neck-shoulder angle. At the primary examination she had only minor symptoms, mainly in the right neck-shoulder angle during rotation motions. She recovered rapidly.

Fig. 5a - Photo of car in cases K1, K2, K3 and K5.

Fig. 5b - The Volvo 850 impacted by the car in case K1, K2, K3 and K5.

The 49-year-old female in case K2 was the front seat passenger of a Volvo S40 (see Fig. 5a) impacting the side of the front part of a Volvo 854 (see Fig. 5b) with a deltaV of 20 km/h according to a crash pulse recorder. Her sitting posture was left turned torso and right turned head. The seat belt pretensioner was activated. She had prior neck/shoulder pain as well as migraine. About 20 minutes after the impact, she felt pricking and numbness in her right arm. At the primary examination two weeks after the accident, she reported VAS never below 1.5. Her symptoms were clearly right sided, pain in neck-shoulder angle when rotating left and right as well as in extension. Sensory disturbances were found in the radial part of her right hand. At the three month examination she had still right sided symptoms, somewhat less intense but still extensive. The symptoms had spread down the body. One year after the accident she reported VAS between 5.2 and 8.5 and she had increased pain and unchanged range of neck motion. The intensity and spread of the symptoms were judged to be affected by her earlier pain history and a stressful life situation.

Cases with seatbelt and airbag: Three belted drivers had a deployed airbag together with activated seat belt pretensioners: cases G1, J1 and K1. Even though the crashes were of quite high impact severity, none of these three experienced intense or long lasting neck symptoms. All of them had an asymmetrical symptom pattern, for two of them possibly related to the seat belt loading on the shoulder. The cases will be presented below.

The 36-year-old driver in a Volvo 850 (case G1) impacted a Ford Escort at a deltaV of a bit above 20 km/h. Directly after the impact, she was in pain all over her body. The day afterwards she had a tender neck and at the primary examination (2.5 weeks later) she had mainly headache (fore and back of head), but also had pain in the left arm and tenderness in the chest. She became progressively better during the first month and reported no pain after two months. The 41-year-old front seat passenger in the same car (G2), wearing a seat belt with activated pretensioners, sustained pain in the middle of the chest and discomfort in the right side of the neck. Although of minor symptom intensity (SI 1), the problems lasted for four months. The second airbag case, J1, also involved a Volvo 850, with a deltaV of 16-20 km/h. The car impacted a Saab 900, forcing the front structure of the Volvo 850 to shear to the right. The 39-year-old driver, with a history of back problems, probably moved in a forward-leftward direction during the impact. Her neck symptoms resulting from this accident were minor, mainly stiffness and lasted less than a month. She also had injuries to her right hand, probably due to the airbag deployment and contusions and pain on the left shoulder from the shoulder belt. The belt loading on the shoulder was probably the reason for symptoms in the left arm and the differences in shoulder strength found at the primary examination. J1 was one of the cases with clinical findings but no subjective symptoms at the examination, so was not possible to fit into a WAD grade. The third airbag case, K1, was a 46-year-old driver of the Volvo S40 in Fig. 5a. She experienced neck stiffness the same day and pain in the neck also developed the day afterwards. She had prior problems in her right neck-shoulder area and also extensive pain in her jaw (sometimes VAS 8). At the primary examination she had extensive pain, which she mainly attributed to the prior jaw problems. Clinical findings in the neck region were only tenderness in the upper part of the neck, classifying her as WAD 2 and SI 1. Her accident related symptoms were judged to be gone within one month. Unlike the front seat passenger in the same car (K2), the driver sustained less intense neck symptoms, which did not last as long. Besides different safety systems in cases K1 and K2, they had quite different neck problem histories as well as different sitting postures during impact.

FACTORS INFLUENCING THE DURATION OF SYMPTOMS: The duration of the impact related neck symptoms is shown for the different occupant loading groups in Table 6. Of the eight cases with symptoms lasting more than one year, only K2 and Q1 had any neck problems in the year prior to the accident.

Table 6 - Symptom duration versus occupant loading groups.

	< 1month	1-3 months	3-12 months	> 12 months
Belt load only	4	4	1	3
Arm res. only				1
Belt load + arm res.	3		1	2
head impact				2
Airbag and belt	1	1	1	

Table 7 shows the relationship between high initial symptom intensity and symptom duration identified by this study. All of the cases with initial high symptom intensity (SI 3) had symptoms lasting more than one year, while the majority of those with minor symptom intensity had symptoms lasting less than three months. No relationship was found between degenerative changes of the cervical spine and the symptom intensity one year later.

Table 7 - Symptom duration versus initial symptom intensity (SI).

	< 1month	1-3 months	3-12 months	> 12 months
Initial SI 1	6	4	3	1
Initial SI 2	2	1		3
Initial SI 3				4

When combining the initial symptom intensity with the symptom intensity at one year for the eight occupants with symptoms lasting more than one year, most combinations could be found, see Table 8.

Table 8 - Initial Symptom intensity (SI) versus SI at one year.

	1 year SI 1	1 year SI 2	1 year SI 3
Initial SI 1	1		
Initial SI 2	1	1	1
Initial SI 3		2	2

One of the eight occupants with symptoms lasting more than one year was diagnosed as having a disc herniation. He was also the only one in this study classified as WAD 3 after one year. The possible factors influencing the outcome of the other occupants with residual problems after one year, ranged from muscle pain due to tensed protractive head posture to psycho-social causes, such as strong negative reactions, bad prognosis expectation and stressful daily activities.

One interesting case is E1, the 23-year-old driver in a Volvo 440 with headache and neck and back pain initially and after one year, but almost pain free at three months. Both the head and neck pain were judged to be due to muscular tension. During the first year she did not receive treatment, but directly after the one year examination she was treated by a physiotherapist. Two months later she had improved head-neck posture and the symptoms were relieved.

At the primary examination all the participants were asked about their own expectations of their prognosis. Four answered pessimistically and all of them had symptoms after one year, which could indicate “state of mood” as an important prognostic factor. In two other cases, the daily life activity stress was judged to have influenced the negative outcome. The physical health of three of the cases was judged to have a negative influence on the recovery. Even if none of these three had prior neck problems, they did have a history of increased sensibility and vulnerability.

DISCUSSION

This study is a limited in-depth study. It cannot give answers on absolute risk factors since it is a selected group where there is no occupant without neck symptoms, but it does show the complexity of causes behind whiplash associated disorders. In a general overview of factors influencing the intensity of initial neck symptoms resulting from frontal impacts, not even deltaV played an important role. When comparing occupants in the same vehicle, no clear similarities in symptom outcome were found, indicating that individual factors probably are more important than car related factors. Based on analyses of each case, occupant sitting posture, occupant loading pattern and individual factors were found to be influential. Despite best efforts, no single car related measure could be pointed out as aggravating the symptoms. Although few cases, none of the three belted drivers with airbag deployment experienced intense or long lasting neck symptoms. Among occupants restraining themselves with their arms symmetrically loading the body, almost all had symmetrical neck symptoms. For those cases with belt load only, there were no findings suggesting pain asymmetry related to shoulder belt side. There were several occupants with right sided neck-shoulder angle pain from head rotating motion without similarities in sitting posture and/or shoulder belt side. Even though some relationships were found, the major conclusion is that the situations resulting in WAD are very diverse and complex.

As a result of the detailed information for each case and the multidisciplinary analysis approach, it was possible to estimate the load transfer to the occupant and the probable occupant kinematics. There were several different kinds of occupant loading in this material causing similar types of symptoms. Consequently it is important to widen the conception of mechanisms behind so called "whiplash injuries". Only half of the occupants had a "typical" whiplash motion, where the torso was restrained by the belt and no head impact was involved.

The WAD classification is not so useful for in-depth studies, and problems occurred in some cases when classifying injuries according to the recommendations of the Quebec Task Force (Spitzer et al. 1995). There were three cases without pain, in which physical signs related to the accident were found. It should be noted that the limit between WAD Grade 2 and 3 is sometimes unclear. Grade 3 means neurological signs, and arm symptoms should not automatically justify Grade 3, as they may be produced by muscular trigger points. Thus the vast majority of the cases in this study were classified as Grade 2, which made it difficult to distinguish between cases with minor and more intense problems. A subdivision of the Grade 2 category has been proposed in the cases where the normal ranges of cervical motion are distinguished from those with limited range of motion (Hartling et al. 2001). The team behind this study support the subdivision, even if it is difficult to distinguish between a normal and a restricted range of motion in some cases. Arm symptoms related to the neck injury should also be included in a prognostic index as they are related to a less favourable outcome (Norris and Watt 1983, Suissa et al. 2001). It is suggested that arm symptoms, regardless of neurological or muscular origin as long as clear neurological deficits are not found, should define a third subgroup of Grade 2.

Of the eight cases with symptoms lasting more than one year, only two had neck symptoms during the year prior to the impact, thus it seems that prior neck problems are not a major risk factor in terms of the duration of neck symptoms resulting from a frontal impact. A relationship between high initial symptom intensity and symptom duration can be seen in this study: higher initial intensity is more likely to result in long-term symptoms. The initial pain intensity has been shown to have a high prognostic relevance (Kasch et al. 2001, Karlsson et al. 2001). The other factors influencing the duration of symptoms found in this study give an indication of the complexity of progression of neck symptoms following frontal impacts. Only in one case could a physical damage to a specific neck structure be identified. For the other cases in this study it was believed that increased muscular tension was the main cause of prolonged pain. Factors such as neck posture, depressed mood, negative self believed prognosis and stressed life situation may have a considerable influence in this respect.

The next step in the efforts of mitigating WAD in frontal impacts would be to study risk factors in statistical data sets and to evaluate these risk factors, bearing in mind the findings in this study.

CONCLUSIONS

This study shows the complexity of WAD in frontal impacts, both with respect to factors that influence occurrence as well as duration of symptoms. Occupant characteristics as well as sitting posture and behaviour at the time of impact are important factors, emphasizing a multidisciplinary approach when analysing and understanding WAD.

Several different occupant kinematics have been identified, all resulting in symptoms classified as whiplash associated disorders. Two cases of unbelted occupants with neck compression mechanism, far from traditional whiplash motion, were found. Compared to occupants restrained only by a seatbelt, occupants with arm resistance influence showed a greater representative of symmetrical neck symptoms.

Factors influencing the duration of symptoms were found to be neck posture related and physical as well as psycho-social factors such as strong negative reactions, bad prognosis expectations and a stressed daily situation. No relationship between long term symptoms and deltaV was found, but those having primary high intensity symptoms were more likely to have long duration symptoms.

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Appendix 1 – Case details

Case: letter is car ID, number is occupant position (1=driver, 2=front pass, 3=left rear pass, 5=right rear pass)

DeltaV class	
a	<6 km/h
b	6-10 km/h
c	11-15 km/h
d	16-20 km/h
e	>20 km/h

Sitting posture	
1	straight forward
2	head turned inwards
3	head turned outwards
4	body leaned inwards
5	body turned inwards and head turned outwards
6	leaned forward

Impact direction
according to clock diagram

Case	Car model	DeltaV class	Impact direction	Gender	Age	Sitting posture	Safety system	Occupant loading	Prior neck symptoms
A1	745	b	11,30	m	38	1	belt	belt left	-
B1	854	c	12	f	34	3	belt	belt left	-
C1	242	b	11,30	m	20	1	belt	b.l. + a.r.	y
C2	242	b	11,30	m	22	1	belt	b.r. + a.r.	y
C5	242	b	11,30	f	19	4	belt	belt right	-
D1	244	a	12	f	34	2	belt	b.l. + a.r.	y
E1	445	d+	12	f	23	1	belt	b.l. + a.r.	-
G1	854	e-	12	f	36	1	belt+ab	b.l. + ab	-
G2	854	e-	12	f	41	1	belt+pret	belt right	y
H1	V70	d-	12	m	53	1	belt+pret	belt left	y
I1	V70	b+	12	f	39	1	belt	belt left	y
J1	855	d	11,30	f	39	1	belt+ab	b.l. + ab	y
K1	S40	d+	12	f	46	1	belt+ab	b.l. + ab	y
K2	S40	d+	12	f	49	5	belt+pret	belt right	y
K3	S40	d+	12	f	27	6	belt	belt left	-
K5	S40	d+	12	f	43	6	belt	belt right	-
L1	445	b+	12	m	54	1	belt	belt left	-
M1	744	b	12	m	24	2	belt	b.l. + a.r.	-
M2	744	b	12	f	20	2	belt	belt right	-
M5	744	b	12	m	24	1	unbelted	arm res.	-
N1	445	d-	12	m	45	2	unbelted	head imp	-
O1	V40	c	12	m	42	2	unbelt.+ab	head imp	-
P1	745	c-	12	f	27	1	belt	belt left	y
Q1	854	a+	12	f	33	1	belt	b.l. + a.r.	y

Case	WAD initial	SI initial	PSS initial	Symptom duration	WAD 1 year	SI 1 year	PSS 1 year
A1	*	1	r	< 1m	0	0	-
B1	2	3	l	> 1y	2	3	l
C1	2	1	s	3-12 m	0	0	-
C2	2	2	s	< 1m	0	0	-
C5	2	1	s	< 1m	0	0	-
D1	1	1	s	< 1m	0	0	-
E1	2	3	s	>1y	2	2	s
G1	2	2	l	1-3m	0	0	-
G2	2	1	r	3-12 m	0	0	-
H1	2	1	r	1-3m	0	0	-
I1	2	1	r	1-3m	0	0	-
J1	*	1	l	< 1m	0	0	-
K1	2	1	r	3-12m	-	0	-
K2	2	2	r	> 1y	2	3	r
K3	2	1	r	1-3m	0	0	-
K5	*	1	r	> 1y	2	1	r
L1	2	1	l	1-3m	0	0	-
M1	2	2	r	< 1m	0	0	-
M2	0	1	r	< 1m	0	0	-
M5	2	2	s	> 1y	2	2	s
N1	2	3	l	> 1y	2	2	l
O1	3	3	l	> 1y	3	3	l
P1	2	1	r	< 1m	0	0	-
Q1	2	2	s	> 1y	2	1	l

SI	Symptom Intensity
1	minor
2	moderate
3	intense

PSS	Primary Symptom Side
l	left
r	right
c	central
s	symmetrical

* WAD, no WAD grade applicable