Assessment of Whiplash Protection in Rear Impacts – Crash Tests and Real-life Crashes

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Summary

Two different studies have been conducted to evaluate the performance of new safety technologies, introduced since 1997, aimed at prevention of whiplash injuries in rear impacts. Crash tests have been performed in two series of 13 seats respectively, and real-life crashes have been analysed to evaluate the effect of Volvo and Saab cars fitted with whiplash systems.

It was found that Volvo and Saab cars fitted with whiplash protection reduced the risk of whiplash injuries with symptoms for more than 6 months with 40% (± 21%) compared with matched models without whiplash protection.

The crash tests showed that the performance varied a lot between the car models. Most seats fitted with whiplash protection showed good results, while models not fitted often showed worse results. Volvo S40, Ford C-max, Nissan Primera and Saab 9-5 got the best results in the latest test series. Some models fitted with whiplash protection got poor results, one model even among the worst. The test showed that design efforts in combination with relatively low cost solutions may perform well.

In the previous test series (2003) Volvo V70, Saab 9-3, Toyota Corolla and Opel Astra (fitted with whiplash protection) showed best results, while Mercedes C-class, VW Polo and Opel Astra (without whiplash protection) showed worst results.

Since the whiplash injury is the most common injury leading to disability it is recommended that both private and non-private purchasers of cars include whiplash performance in their choice of car.

It is important that consumer test programs include whiplash protection and that test results can be available when buying a car. Therefore it is important that established test programs, such as Euro NCAP, also include a whiplash protection evaluation.

Background

In October 1997 the Swedish parliament decided upon the new road traffic safety policy in Sweden, the so-called Vision-Zero. An important part in the policy is to minimise health losses and not accidents or injuries in general. Health losses include fatal injuries and severe injuries where the person not is recovering within reasonable time, i.e. the focus is on the public health problem.

Apart from fatalities, injuries leading to disability reported by insurance companies are a good indication of the number of serious road traffic injuries. They also give a good picture of both the typical injuries and the type of crashes that primarily should be in focus for road traffic safety actions. To date more than 3,500 disabled annually are reported (with a disability of at least 10% according to the classification used by Swedish insurance companies). More than 50% of these are whiplash injuries. It is therefore important that the society focuses on reducing whiplash injuries.

Safer cars may count for a large part of the reduction of whiplash injuries resulting in permanent disability. Primarily the car seats need to be better, but also other countermeasures may be effective. In this report the ability of cars and especially car seats to protect from whiplash injury in rear impacts is evaluated.

Real-life whiplash injury risks have been studied by analysis of vehicles that have new whiplash protection systems introduced since 1997. Whiplash protection has been studied by crash tests of seats.

Whiplash injuries

The word whiplash describes a dynamic movement, but has also become a definition of a soft tissue injury in the neck. The injury occurs in the fast whiplash motions of the head in both rear-end and frontal impacts but also in lateral impacts and rollovers.

The symptoms might be several, pain and stiffness in the neck, numbness, headache etc. The symptoms may occur directly after the crash, within a couple of hours or within some days after the crash.

In modern cars on the Swedish market whiplash injuries accounts for approximately 70% of all injuries leading to disability. Half of the injuries occur in low to moderate speed rear-end crashes and a third in frontal impacts. Most occupants reporting whiplash injuries recovers within a week, while between 5% and 10% will get more or less life lasting problems.

The injury mechanism is still not fully known, but several hypotheses exist. It is therefore important that measures to reduce whiplash injuries focus on several possible injury mechanisms. Whiplash preventive measures have so far been focussed on developments of the seat. Since the 70s head restraints have been implemented more and more frequently. To date all seating positions in most car models are fitted with head restraints. The whiplash injury reducing effects of head restraints have been shown to be relatively low, 5%-10%. In order to increase the vehicle crashworthiness in high-speed rear end crashes, vehicle seats have become stiffer since the late 80s. Stiffer seats have probably increased the whiplash injury risks in low-speed rear-end crashes.

Based on this knowledge more advanced whiplash protection devices have been introduced on the market. The better protection is achieved through improved geometry and dynamic properties of the head restraint or by active devices that moves in a crash as the body loads the seat. The main aims are to minimise the relative motion between head and torso, to control energy transfer between the seat and the body and to absorb energy in the seat back.

To date several systems exist, AHR (Active Head Restraint) in several car models, WhiPS (Whiplash Prevention System) in Volvo and Jaguar, WIL (Whiplash Injury Lessening) in Toyota. AHR was firstly introduced in Saab cars in 1997 (SAHR). To date it is the most common whiplash protection concept on the market and exists in several models from for example Opel, Ford, Nissan and Peugeot. AHR is a mechanical system that actively moves the head restraint up and closer to the head and in a crash. Saab has apart from the head restraint also developed the seat back to better support the torso in a rear end crash. WhiPS was first introduced in Volvo cars in 1998. The seat back is in a crash moved rearwards and yields in a controlled way to absorb energy. The Toyota system WIL has no active parts and is only working with improved geometry and softer seat back.

Studies have been presented showing the effect of the Saab AHR and Volvo WhiPS indicating an injury reducing effect of approximately 40-50% (Viano and Olssén 2001, Insurance Institute for Highway Safety (IIHS) 2002, Jakobsson 2004, Krafft et al 2003).

Evaluation of Whiplash Protection Based on Real-life Crashes

Method and Material

Insurance data was used to evaluate the whiplash reducing effect in Volvo and Saab cars equipped with whiplash protection systems. Cars with whiplash protection systems were compared with similar models not equipped with whiplash systems. The proportions of injuries in the two car categories were compared. The limited number of cases only made it possible to study the average effect of all Saab and Volvo models together, see Table 1. The study included all reported whiplash injuries in rear-end crashes to the insurance company Folksam between Jan 1998 and Feb 2003. Only front seat occupants (drivers and front seat passengers) were included.

Table 1. Car models studied (MY=model year)

Car models without whiplash systems	Car models with whiplash systems
Saab 9000	Saab 9-5
Saab 900, MY 1993-97	Saab 9-3
Volvo S40/V40, MY1996-99	Volvo S40/V40, MY 2000-
Volvo 850	Volvo S80
Volvo V70/S70, MY 1998-00	Volvo S70/V70, MY 2000-

All together 663 drivers and front seat passengers were studied, whereof 58 in cars equipped with whiplash protection systems and 605 in cars without.

With help of questionnaires the occupants reporting a whiplash injury have answered questions around:
- symptoms (neck pain, problems to move the head, head ache, pain in thoracic and lumbar spine, and other symptoms)

- the duration of whiplash symptoms (no symptoms, initial symptoms, symptoms for more than 1 month, symptoms for more than 6 months)
-frequency of symptoms (every day, more than once a week, more than once a month, less often than above).

28% of the identified persons did not answer the questionnaire. In order to get information of the symptom duration of these occupants, the duration was classified according to insurance payments. I those cases this was not reliable the claims adjusters were contacted for their judgements. In total 5 persons were excluded from the study.

In the analysis the occupants were divided in two groups based in symptom duration and frequency:
- Those not reporting any symptoms and those with symptoms for less than six months.
- Those with symptoms for more than 6 months and where the symptoms occurred at least once a week.

As control group and measure of exposure, to calculate the injury reducing effect, all traffic injuries reported to Folksam was used for the same vehicle models as described in Table 1 and for the same time period. All crash types irrespective of personal injuries were included.

Results

Table 2 presents the number of occupants with various symptoms duration in cars with and without whiplash protection.

Table 2. Number of front seat occupants with whiplash symptoms less than 6 months and more than 6 months in Saab and Volvo models with and without whiplash protection.

	Female drivers		Male drivers		Female front seat pass.		Male front seat pass.	
	0-6 m	> 6 m	0-6 m	> 6 m	0-6 m	> 6 m	0-6 m	> 6 m
Without whiplash protection	94	68	170	89	102	35	37	10
With whiplash protection	10	1	19	6	10	7	4	0

The risk of whiplash related symptoms for more than 6 months was found to be 39.7% ± 21.1% (95% confidence interval) higher in Saab and Volvo cars without whiplash protection compared with the corresponding models without whiplash protection, see Table 3. The effect was calculated by comparing the number of occupants with different symptom duration with the total number of reported crashes in the same models for the same time period.

Table 3. Number of reported crashes of Saab and Volvo cars with and without whiplash protection, and numbers of front seat occupants with various symptom durations.

	Reported crashes (all crash types)	Symptoms 0-6 months (rear-end crashes)	Symptoms > 6 months (rear-end crashes)
Without whiplash protection	15 892	403	202
With whiplash protection	1 813	43	14

Evaluation of whiplash protection based on crash tests

When evaluating crashworthiness of cars with crash tests it is important that the test mirror crashes where injuries occur. It is therefore necessary to have knowledge from real-life crashes about correlation between crash severity and injury outcome. This work focuses the risk of whiplash injury in rear end collision.

To get relevant crash test results it is also necessary to have a biofidelic dummy that can measure parameters predicting injury. Such measurements must be evaluated and linked to real-life injuries to get thresholds for injury. Below is a summary of the knowledge in this area.

Crash severity

Data from real-life crashes where the cars have been fitted with crash recorders have been helpful to identity test conditions. The tests should mirror such crash severity that in real-life crashes generates a certain injury risk. The link between change of velocity, the car acceleration and risk of whiplash injury has been evaluated for 4 car models of the same make. In total 131 crashes including 177 front seat occupants were studied.

Figures 1 and 2 show the number of crashes and whiplash injuries in relation to the cars change of velocity and mean acceleration. Figure 1 shows that most rear-end crashes occur at relatively low change of velocity, below 10 km/h, while crashes where the whiplash injury risk is high is significantly higher, 15 km/h and higher. Mean acceleration seems to be more important than change of velocity in explaining whiplash injury risk. In the studied crashes only one person sustained a whiplash injury leading to symptoms for more than 1 moth as long as the mean acceleration was below 3 g, see Figures 2 and 5. The risk increases rapidly at a mean acceleration above 4 g. At 7 g the risk seems to approach 100% (based on the studied vehicle models). The combination of change of velocity and mean acceleration for all occupants can be seen in Figure 5.

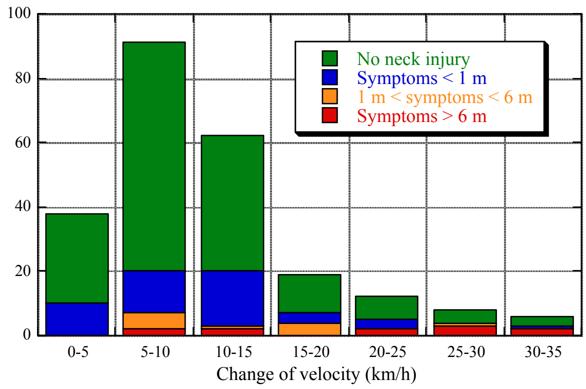

Figure 1. Number of crashes and injuries in intervals of change of velocity.

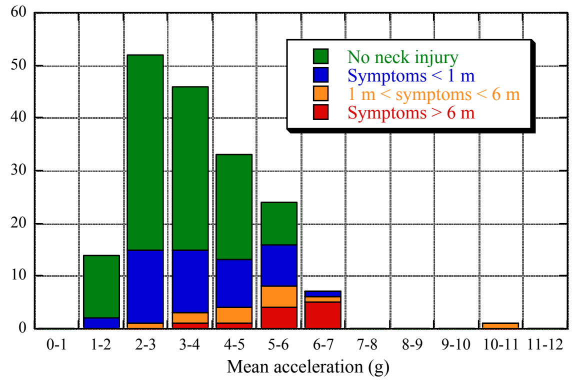

Figure 2. Number of crashes and injuries in intervals of mean acceleration.

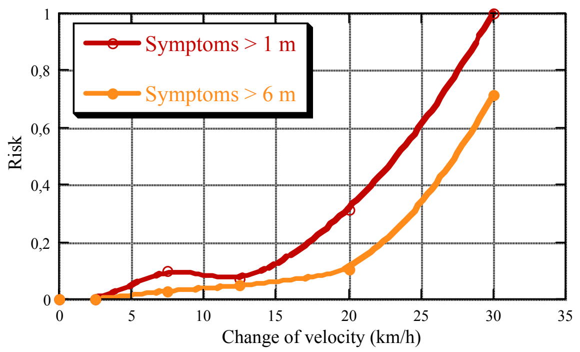

Figure 3. Whiplash injury risk in intervals of change of velocity.

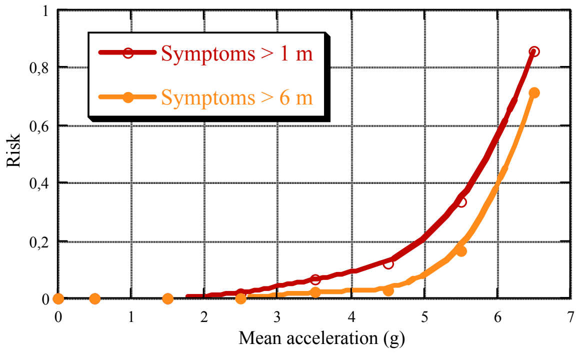

Figure 4. Whiplash injury risk in intervals of mean acceleration.

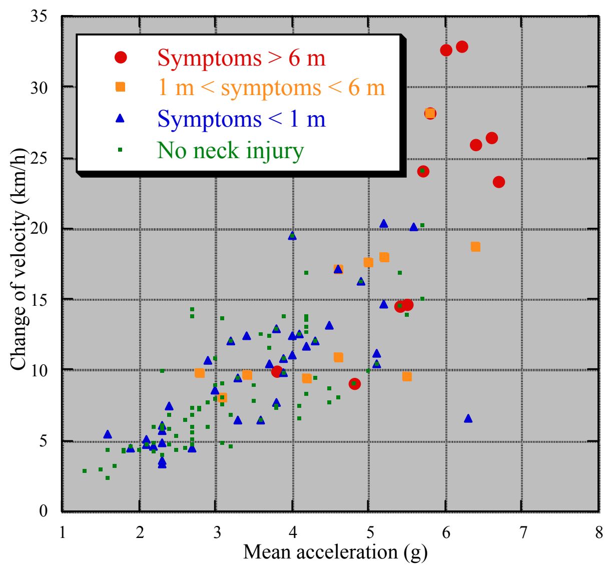

Figure 5. Change of velocity and mean acceleration for occupants with and without whiplash injury.

Injury criteria

The injury mechanism or mechanisms of the whiplash injury is not yet fully understood. Many hypotheses exist and some whiplash injury criteria have been proposed. The most frequently used ones are NIC_{max} (Neck Injury Criterion) and N_{km}. But also others have been used, such as LNL (Lower Neck Load), shear force and tension (Fx and Fz) and bending moment (My). Many studies have also proposed that whiplash injuries may occur in the rebound phase of the occupant motion. Approximately a third of all whiplash injuries occur in frontal impacts. Studies have indicated that the injury in these crashes occurs in the flexion phase after seat belt contact. Similar motions and load conditions may occur in the rebound phase of a rear-end crash. To date no dummy has been validated for that "rebound" motion. Rebound velocity may be used to mirror the injury risk in that motion.

NIC_{max} (Neck Injury Criterion), N_{km} and rebound velocity mirror injury risks in three different phases of the crash. NIC_{max} measure neck loadings before contact with the head restraint; N_{km} shows neck loadings during contact with the head restraint; and rebound velocity indicates neck loading levels in the rebound phase.

In recent published studies injury criteria have been evaluated by comparing dummy readings from reconstructed crashes with injuries under real-life conditions. The crash severity was known from crash recorders and the injury outcomes were also known. The injuries were divided in duration of whiplash symptoms, above and below one month. A clear correlation between both NIC_{max}, N_{km} and injury risk was found. Injury risk was found to be approximately 10%-20% at NIC_{max} of 15 and of N_{km} 0.3. To avoid high whiplash injury risk it is advisable that NIC_{max} is below 15 and N_{km} below 0.3. Figures 6 and 7 illustrate these risk assessments for NIC_{max} and N_{km} respectively.

Regarding rebound velocity, comparisons of whiplash injury risks in frontal impacts could be studied. By such comparison it can be estimated that injuries may occur at head rebound velocity above 5 m/s.

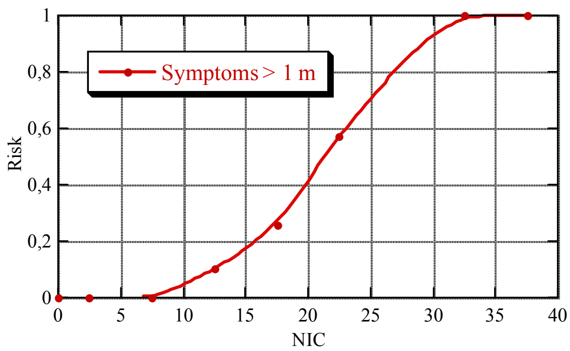

Figure 6. Injury risk versus NIC_{max}.

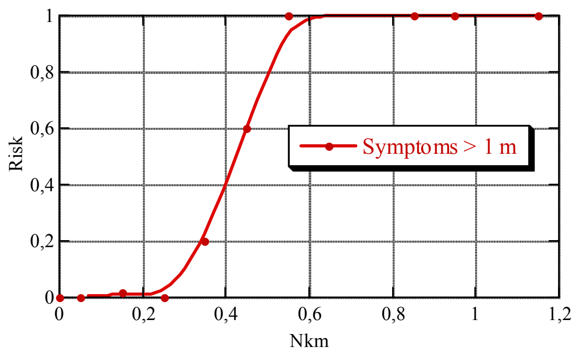

Figure 7. Injury risk versus N_{km}.

Method and material

Test program

In total two test series have been conducted using car seats on a sled. The first one in 2003 included 13 driver seats and the second test series in 2004 included 13 additional seats. In addition to that one seat with and without after market whiplash protection were tests according to the test procedure 2004. All seats were mounted at a test sled. The crashes were made at three crash severities to measure the protective effect at several crash conditions. Based on the results from crash recorders described earlier, 3 test conditions at different velocity and acceleration were chosen, see Table 4. As shown in Figures 2 and 5, most injuries with long-term symptoms occur at mean acceleration between 4 and 7 g. The three crashes covers that area, 4.5 g represents low risk but where many crashes occur, 5.5 g represents medium risk and medium exposure, while 6.5 g represents high risk but low exposure.

Table 4. Test speed and acceleration

Test	Speed	Mean acceleration
1 – Low severity	16 km/h	4,5 g
2 – Mid severity	16 km/h	5,5 g
3 – High severity	24 km/h	6,5 g

The crash pulses of the two test series, 2003 and 2004, are presented in Figures 8 and 9. The 2nd test pulse was changed in the 2nd test series from trapezoidal shape to triangular shape, but with the same test speed and mean acceleration. The test series should not be directly compared because of this change. However, the results should be very close to one another.

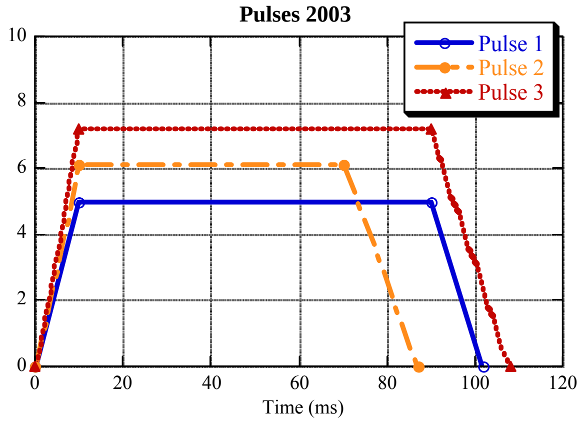

Figure 8. Pulses used in the first test series in 2003.

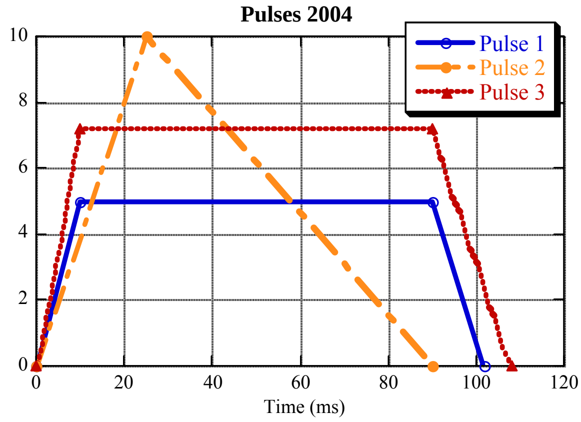

Figure 9. Pulses used in the second test series in 2004.

Other test specifications (a complete test specification is found in a separate document)

- Dummy: BioRID (Denton, version E)
- Measurements: Acceleration in head, chest, T1 and pelvis, forces and moments in upper and lower neck, belt load, head and chest velocity from film analysis.
- Head restraint in mid positions.
- Seat back angle: 25 degrees using an H-point dummy
- Seat belt: Generic seat belt (non-car specific but geometry close to car geometry).

Table 5 describes the car models from where the seats were tested. It also lists how the seats were assembled. Several manufacturers deliver seats in parts. These seats have been assembled by authorised dealer workshops.

Table 5. Model list with status of the seat assembling.

Seat / car model	Model year	Seat assembled by manuf	Seat assembled by dealer
Volvo S40 4D 1,8	2004	x	
SAAB 9-5 4D 2,0t	2004	x	
Audi A3, 3D 1,6 l	2004	x	
Opel Meriva, 5D, 1,6l Enjoy	2004	x	
Opel Meriva, 5D, 1,6l Enjoy, option whiplash protection	2004	x	
Ford Focus, 5D, Ambiente	2004		x
Ford C-max, 5D, Ambiente	2004		x
VW Touran, 5D 1,6l, FSI	2004	x	
Toyota Avensis 4D 1,8l	2004	x	
Seat Ibiza, 3D, 1,4l 16v	2004	x	
Nissan Primera Combi, 1,8l	2004		x
Mitsubishi Space Star, 5D	2004		x
Citroen C3, 5D, 1,4l	2004		x

Measurements and criteria

To rate the various seats regarding risk of whiplash injury 3 parameters were measured and used, NIC_{max}, N_{km} and head rebound velocity. The overall rating is based on point scores. In the calculation of points, the seats got points if each measured parameter exceeded critical limits as described in Table 6. Two limits per injury criteria were used and maximum 2 points for NIC_{max} and N_{km} and were given, while maximum 1 point was given for head rebound velocity. High point scores indicate poor protection levels.

For each car model all points were summed for all three tests. To be regarded as a low risk seat maximum 5 point was allowed (labelled green). Between 5.1 and 10 points the seat was regarded as having average risk (Labelled yellow), and above 10.1 points the seat model was regarded as having high risk (labelled red). Each measurement described in Tables 7 and 8 is also colour labelled according to the limits in table 6.

Table 6. Critical limits and points.

Criterion	Lower limit	Upper limit	Green Low risk	Yellow Medium risk	Red High risk
NIC_{max}	$> 15\ m^2/s^2$	$> 18\ m^2/s^2$	$\leq 15\ m^2/s^2$	$15 < NIC_{max} \leq 18$	> 18
N_{km}	> 0,3	> 0,4	≤ 0,3	$0,3 < N_{km} \leq 0,4$	> 0,4
Rebound velocity	> 4,5 m/s	> 6,0 m/s	≤ 4,5 m/s	4,5 < Vel. ≤ 6,0	> 6,0

Results

Table 8 shows all test results from 2004 using the crash test pulses described in Figure 9, and Table 9 all test results from 2003 using the crash pulses described in Figure 8. Table 10 shows test results from a Toyota Corolla, model year 1993, both with and without an after market whiplash protection device. In those tests the pulses described in Figure 9 were used. Note that the results in Table 9 are not directly comparable to the results in Tables 8 and 10 due to the In average cars fitted with whiplash protection scored better results, see Table 7, but there are also large differences within those seat with whiplash protection. Some of these seats did not get good ratings.

Table 7. Average of measurements for cars with and without whiplash protection.

	NIC_{max}	N_{km}	Rebound velocity
Seats with whiplash protection	16,6	0,34	4,4
Seats without whiplash protection	21,5	0,43	4,6

Table 8. Test results for tests in 2004.

	Pulse	NIC	Points	Nkm	Points	Re-bound	Points
Audi A3 (Model year 2005)	Low	14,6	0,0	0,37	1,4	4,60	0,1
Yellow (8,5)	Medium	23,9	2,0	0,49	2,0	4,80	0,2
Equipped with whiplash protection	Severe	21,1	2,0	0,31	0,2	5,50	0,7
Audi A3 (Model year 2004)	Low	19,7	2,0	0,40	2,0	4,80	0,2
Red (13,5)	Medium	27,6	2,0	0,41	2,0	5,02	0,3
Equipped with whiplash protection	Severe	27,5	2,0	0,40	2,0	6,32	1,0
Citroen C3	Low	18,0	2,0	0,23	0,0	4,62	0,1
Yellow (9,0)	Medium	30,9	2,0	0,28	0,0	5,06	0,4
No whiplash protection system	Severe	26,9	2,0	0,39	1,8	5,58	0,7
Ford C-max	Low	11,4	0,0	0,10	0,0	4,11	0,0
Green+ (2,2)	Medium	15,8	0,5	0,13	0,0	4,68	0,1
No whiplash protection system	Severe	14,9	0,0	0,33	0,6	6,06	1,0
Ford Focus	Low	17,2	1,5	0,16	0,0	3,99	0,0
Yellow (7,9)	Medium	29,1	2,0	0,26	0,0	4,61	0,1
No whiplash protection system	Severe	27,3	2,0	0,54	2,0	4,97	0,3
Mitsubishi Space Star	Low	17,0	1,3	0,32	0,4	4,62	0,1
Yellow (9,4)	Medium	24,7	2,0	0,35	1,0	4,85	0,2
No whiplash protection system	Severe	23,9	2,0	0,37	1,4	6,00	1,0
Nissan Primera	Low	9,2	0,0	0,28	0,0	4,04	0,0
Green (3,1)	Medium	10,9	0,0	0,33	0,6	4,37	0,0
Equipped with whiplash protection	Severe	14,4	0,0	0,60	2,0	5,30	0,5
Opel Meriva (Standard equipment)	Low	20,0	2,0	0,46	2,0	4,65	0,1
Red (13,4)	Medium	27,0	2,0	0,51	2,0	4,90	0,3
No whiplash protection system	Severe	29,5	2,0	0,53	2,0	6,36	1,0
Opel Meriva (Extra equipment)	Low	14,8	0,0	0,12	0,0	4,35	0,0
Yellow (7,2)	Medium	19,3	2,0	0,10	0,0	4,77	0,2
Equipped with whiplash protection	Severe	20,1	2,0	0,41	2,0	6,09	1,0
SAAB 9-5	Low	10,9	0,0	0,26	0,0	3,77	0,0
Green (4,2)	Medium	18,0	2,0	0,28	0,0	3,55	0,0
Equipped with whiplash protection	Severe	24,6	2,0	0,31	0,2	4,33	0,0
Seat Ibiza	Low	16,4	0,9	0,47	2,0	3,83	0,0
Yellow (9,4)	Medium	27,2	2,0	0,23	0,0	4,12	0,0
No whiplash protection system	Severe	23,0	2,0	1,11	2,0	5,28	0,5
Toyota Avensis	Low	15,3	0,2	0,16	0,0	4,06	0,0
Yellow (7,3)	Medium	19,7	2,0	0,27	0,0	4,62	0,1
Equipped with whiplash protection	Severe	25,0	2,0	2,19	2,0	6,31	1,0
Volvo S40	Low	10,9	0,0	0,12	0,0	2,75	0,0
Green+ (1,1)	Medium	14,2	0,0	0,19	0,0	3,33	0,0
Equipped with whiplash protection	Severe	15,5	0,3	0,31	0,2	5,40	0,6
VW Touran	Low	13,1	0,0	0,34	0,8	4,79	0,2
Yellow (9,1)	Medium	22,2	2,0	0,38	1,6	5,27	0,5
Equipped with whiplash protection	Severe	22,3	2,0	0,35	1,0	6,56	1,0

Table 9. Test results for tests in 2003.

Model	Pulse	NIC	Points	Nkm	Points	Head rebound vel.	Points
Audi A4	**16kph/4,5g**	16,3	0,9	0,22	0,0	4,11	0,0
Yellow (5,5 points)	**16kph/5,5g**	23,3	2,0	0,29	0,0	4,35	0,0
No whiplash protection system	**24kph/6,5g**	24,5	2,0	0,31	0,2	5,18	0,5
BMW 3-serie	**16kph/4,5g**	15,7	0,5	0,68	2,0	4,43	0,0
Red (11,3 points)	**16kph/5,5g**	18,8	2,0	0,81	2,0	4,83	0,2
No whiplash protection system	**24kph/6,5g**	29,7	2,0	0,57	2,0	5,56	0,7
Ford Mondeo	**16kph/4,5g**	12,9	0,0	0,28	0,0	3,60	0,0
Green (2,6 points)	**16kph/5,5g**	16,6	1,1	0,32	0,4	4,57	0,0
Whiplash protection system	**24kph/6,5g**	15,1	0,1	0,35	1,0	4,60	0,1
Mercedes C-class	**16kph/4,5g**	24,0	2,0	0,52	2,0	4,41	0,0
Red (10,6 points)	**16kph/5,5g**	26,4	2,0	0,57	2,0	4,91	0,3
No whiplash protection system	**24kph/6,5g**	28,4	2,0	0,31	0,2	4,65	0,1
Opel Astra (Standard)	**16kph/4,5g**	19,7	2,0	0,45	2,0	3,89	0,0
Red (12,1 points)	**16kph/5,5g**	19,1	2,0	0,55	2,0	3,58	0,0
No whiplash protection system	**24kph/6,5g**	20,7	2,0	0,53	2,0	4,67	0,1
Opel Astra (Optional)	**16kph/4,5g**	16,0	0,7	0,30	0,0	3,55	0,0
Green (4,7 points)	**16kph/5,5g**	18,0	2,0	0,28	0,0	3,67	0,0
Whiplash protection system	**24kph/6,5g**	19,9	2,0	0,21	0,0	4,17	0,0
Peugeot 307	**16kph/4,5g**	17,2	1,5	0,21	0,0	4,25	0,0
Yellow (8,4 points)	**16kph/5,5g**	19,0	2,0	0,39	1,8	4,68	0,1
Whiplash protection system	**24kph/6,5g**	22,1	2,0	0,28	0,0	5,99	1,0
Renault Megane	**16kph/4,5g**	17,0	1,3	0,23	0,0	4,31	0,0
Yellow (9,9 points)	**16kph/5,5g**	19,8	2,0	0,42	2,0	4,75	0,2
No whiplash protection system	**24kph/6,5g**	18,3	2,0	0,55	2,0	5,24	0,5
Saab 9-3	**16kph/4,5g**	11,3	0,0	0,22	0,0	3,24	0,0
Green+ (0,9 points)	**16kph/5,5g**	14,3	0,0	0,18	0,0	3,22	0,0
Whiplash protection system	**24kph/6,5g**	16,4	0,9	0,29	0,0	4,50	0,0
Skoda Fabia	**16kph/4,5g**	17,1	1,4	0,29	0,0	2,98	0,0
Yellow (7,5 points)	**16kph/5,5g**	20,9	2,0	0,24	0,0	3,39	0,0
No whiplash protection system	**24kph/6,5g**	24,5	2,0	1,05	2,0	4,68	0,1
Toyota Corolla	**16kph/4,5g**	14,7	0,0	0,14	0,0	3,96	0,0
Gren (3,0 points)	**16kph/5,5g**	15,0	0,0	0,17	0,0	4,14	0,0
Whiplash protection system	**24kph/6,5g**	16,5	1,0	0,87	2,0	4,25	0,0
Volvo V70	**16kph/4,5g**	9,1	0,0	0,09	0,0	2,35	0,0
Green+ (0,0 points)	**16kph/5,5g**	12,8	0,0	0,15	0,0	2,38	0,0
Whiplash protection system	**24kph/6,5g**	14,1	0,0	0,22	0,0	4,44	0,0
VW Polo	**16kph/4,5g**	16,6	1,1	0,42	2,0	3,68	0,0
Red (11,1 points)	**16kph/5,5g**	18,0	2,0	0,43	2,0	3,49	0,0
No whiplash protection system	**24kph/6,5g**	19,2	2,0	0,67	2,0	4,01	0,0

Table 10. Test results of Toyota Corolla, model year 1993,
with and without after market whiplash device.

Seat	Pulse	NIC	Points	Nkm	Points	Re-bound	Points
Toyota Corolla (Model year 1993)	**Low**	15,8	0,5	0,57	2,0	4,13	0,0
Red (10,7)	**Meduim**	17,9	1,9	0,74	2,0	4,40	0,0
No whiplash protection system	**Severe**	20,8	2,0	0,66	2,0	5,00	0,3
Toyota Corolla (Model year 1993)	**Low**	13,5	0,0	0,46	2,0	3,91	0,0
Yellow (6,8)	**Meduim**	12,2	0,0	0,48	2,0	3,96	0,0
Equipped with whiplash protection*	**Severe**	35,3	2,0	0,30	0,0	5,80	0,8
*after market device (yielding seat back)							

Discussion and conclusions

Whiplash injuries leading to permanent disability are serious and also common in relation to other disabling injuries. All forces in society must focus this problem to be able to improve whiplash protection and to reduce the health losses due to this injury type. The initiative from the Swedish National Road Administration (SNRA) and Folksam shows that it is possible to rate the performance of various car models and to separate those cars with lower and higher risk. Furthermore, it shows that consumers by making a good choice may influence their risk of whiplash injury in case of a rear end crash.

The testing is focusing the seat performance since the seat plays a major role in protecting the occupants from whiplash injury. This approach is relevant in today’s situation. In the future vehicle mass and deformation performance will become important additional features to analyse.

The results from this study are very positive and show that it is a large potential in improving the construction of car seats. The best seats have both in real-life crashes and in crash test showed high effectiveness regarding whiplash injury reduction. However, there is still a potential in further improvements of the best performing seats. Therefore consumers should choose among the best performing seats until the average safety level has been significantly better.

It is difficult to estimate the reduction of whiplash injuries if all consumers would pick the best performing seats. The injury reducing effect is probably not lower than 50% considering the results from real-life crashes. The Volvo and Saab cars without whiplash protection that was used as reference cars in the evaluation of the effect of those fitted with whiplash protection had in comparison to other models without whiplash protection one of the lowest whiplash rates. Therefore the figure of 40% reduction is probably an under estimation compared to the effect if all vehicles models would have been included.

The crash tests indicate a large variation in protection. Some seats did not perform well even in the low severity test, while some seats performed well even in the high severity test. The results also show a large variation even within those seats equipped with more advanced whiplash protection systems. They were represented in both the best and worst group. It stresses the need for consumer test programmes as a help for the consumers in picking the best cars. Identifying that a seat has whiplash protection devices is not enough.

In these two test series 27 seat models were tested. Of course it is important that more models are tested to be able to give a more complete picture. It is also important that further studies of real-life crashes are conducted to verify the crash test performance.

Folksam and SNRA recommend both private and non-private purchasers of cars (fleet buyers) such as governmental authorities, local authorities, large companies and organisation to focus also on whiplash injury risk and to choose among those cars showing best results also in rear-end crash test and in studies of real-life crashes. Folksam and SNRA recommend car manufacturers to rapidly implement best possible protection for whiplash injury in their car models. It is also important that other consumer test programmes, such as Euro NCAP include rear-end tests and whiplash rating in their rating methods.

Finally it is important to stress that it is important to make further efforts in improving car seats and also other safety technology to reduce whiplash injuries leading to permanent disability.