SEAT BELTS AND NECK INJURIES

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ABSTRACT

This article, part of a recently completed research project on safety belts, presents results on neck injuries. A total of 3927 injured front seat occupants (drivers and passengers) involved in two-car crashes were considered. Among them, 725 sustained a neck sprain (ICD-9:847.0), some of them may have sustained other injuries as well. The more serious injuries to the cervical spine were more prevalent among the unbelted occupants. Neck sprains were relatively more numerous among belted occupants compared with unbelted ones with a relative risk estimate of 1.68. Similar results hold also for subsets of the data on different types of collisions; the relative risks range from 1.39 to 2.42. A loglinear model was constructed for the odds ratio (neck sprain versus no neck sprain) taking into account the factors seat belt, direction of impact, authorized speed limit and vehicle weight. The resulting relative risk estimate (belted VS unbelted) is now 1,58. The results raise questions about seat belts and protection against neck sprains.

1. INTRODUCTION

There is no doubt about seat belt effectiveness in the reduction of severe and fatal injuries (AIS≥3) in road accidents (NTSB, 1988; Evans, 1986; Dickinson, 1986; Hartemann 1986; Cesari et al. 1981). Laberge-Nadeau et al. (1988) show that belted occupants sustain a different spectrum of injuries to specific body regions from those sustained by unbelted occupants. The neck and cervical spine constitute such a region. Deans et al. (1987) reported that occupants wearing seat belts experience neck pain more frequently than unbelted occupants. A study by Huston and King (1988) simulates the mechanics resulting from rapid deceleration during a crash: They show that for a belted occupant, involved in a frontal or side impact opposite direction, the typical result is a forward-backward movement and often a rotation of the head which leads to twisting of the neck. For a rear crash or side impact same direction, the extension of the neck is a backward-forward movement and often a rotation of the head.

Neck injuries are a major cause of disability following car accidents (Deans et al., 1987; Laberge-Nadeau and Joly, 1988; Larder et al., 1989). The compensation costs to cover lost days of work can be relatively high. Neck injuries, except for serious ones such as fractures or neurological trauma, are under-reported (Larder et al., 1985) because of the delayed onset of symptoms. There is also a problem of defining the nonspecific symptoms of minor injuries of the soft neck tissue (classification of the severity).

This paper concentrates on cervical injuries, mainly neck sprains, sustained by belted and unbelted front seat occupants involved in similar crashes.

2. METHOD

The data were obtained from the governement insurance board (Régie de l'assurance automobile du Québec, RAAQ) which covers all road accidents with injuries that occur in the province of Québec. Our data files was constructed by linking the following computer files:

- insurance claims (victim information)
- accidents (police accident reports)
- car registrations (vehicle information)
- drivers' licences (driver information).

This data set was examined to check and to evaluate completeness, representativity and quality (Laberge-Nadeau, 1984). To correct and to improve the data set, additional information was added from the medical records (injury descriptions including pains and updates to these descriptions for at least one year after the crash) and from the police reports (accident configurations) at the RAAQ. Thus our data set has the advantage that it includes delayed reports of neck sprains.

The injuries were coded using the International Classification of Diseases, 9th edition (ICD-9). Their severity was quantified with the Abbreviated Injury Scale (AIS, 1980) and ISS; for a global score the major AIS was used (MAIS).

Similar accidents were grouped together according to the following variables:

- authorized speed limit (<50km/hr, >50 km/hr)
- vehicle weight (<1200, 1200-1599, 1600-1899, 1900-2400 kg)
- crash configuration (front or side impact opposite direction, rear or side impact same direction).

For this study, only injured front seat occupants in two-car crashes were considered.

3. ANALYSES AND RESULTS

The data set contains 3927 front seat occupants who were injured in a two car crash. Front or side impacts with cars moving in the opposite direction accounted for 3176 cases, rear or side impacts with cars moving in the same direction for the remaining 751 cases. Table 1 gives the distribution for serious and minor cervical spine injuries. Clearly, the distributions for belted and unbelted occupants are different. Serious cervical spine injuries occur more frequently among unbelted occupants, minor ones more frequently among belted ones. This reduction in severe and fatal cervical spine injuries is considerable for those wearing a seat belt; it is most noticeable in collisions with a car of lighter weight and in collisions between cars moving in opposite directions.

Table 1 : Distribution (in percentage) of the degree of severity of cervical injuries to front seat occupants by type of impact

Type of impact		Severity of Cervical injury MAIS (1,2)	MAIS ≥ 3	Total (frequency)	Chi-square statistic (1 df)	P Value
2-car crash	belted	486 (48)	10 (2)	496 (100)		
	unbelted	148 (93)	11 (7)	159 (100)	5,9	0,0149
Collision with a car of lighter weight	belted	181 (99)	1 (1)	182 (100)	10,7	0,0011
	unbelted	44 (90)	5 (10)	49 (100)		
Front or side impact opposite direction	belted	272 (97)	8 (3)	280 (100)	4,4	0,0359
	unbelted	84 (91)	8 (9)	92 (100)		

Table 2 shows the breakdown of these injuries into fractures and sprains. Unbelted occupants sustain a greater number of fractures.

Table 2 : Distribution (in percentage) of the nature of cervical injuries to front seat occupants

Nature of cervical injury (MAIS)	Belted	Unbelted	Total (frequency)	Chi-square statistic(1 df)	P Value
Fracture	14 (3)	14 (9)	28 (4)		
Sprain	470 (95)	144 (91)	614 (94)	12,22	0,0022
Unspecified	12 (2)	1 (1)	13 (2)		
Total	496 (100)	159 (101)	655 (100)		

Among the 3927 occupants, 725 (18%) sustained a neck sprain, and for 80% of them (614) this diagnosis constituted their major injury. Among the belted occupants 21% had a neck injury but of the unbelted occupants only 14% sustained a neck injury.

Table 3 compares, for injured occupants, the risks of sustaining a neck sprain for different factors such as seat belt, direction of impact, authorized speed limit and vehicle weight. The relative risks range from 1,17 to 4,24 with 1,68 for belted versus unbelted injured occupants. Occupants involved in a rear or side impact same direction were four times as likely to sustain a neck sprain compared with those involved in a front or side impact opposite direction accident.

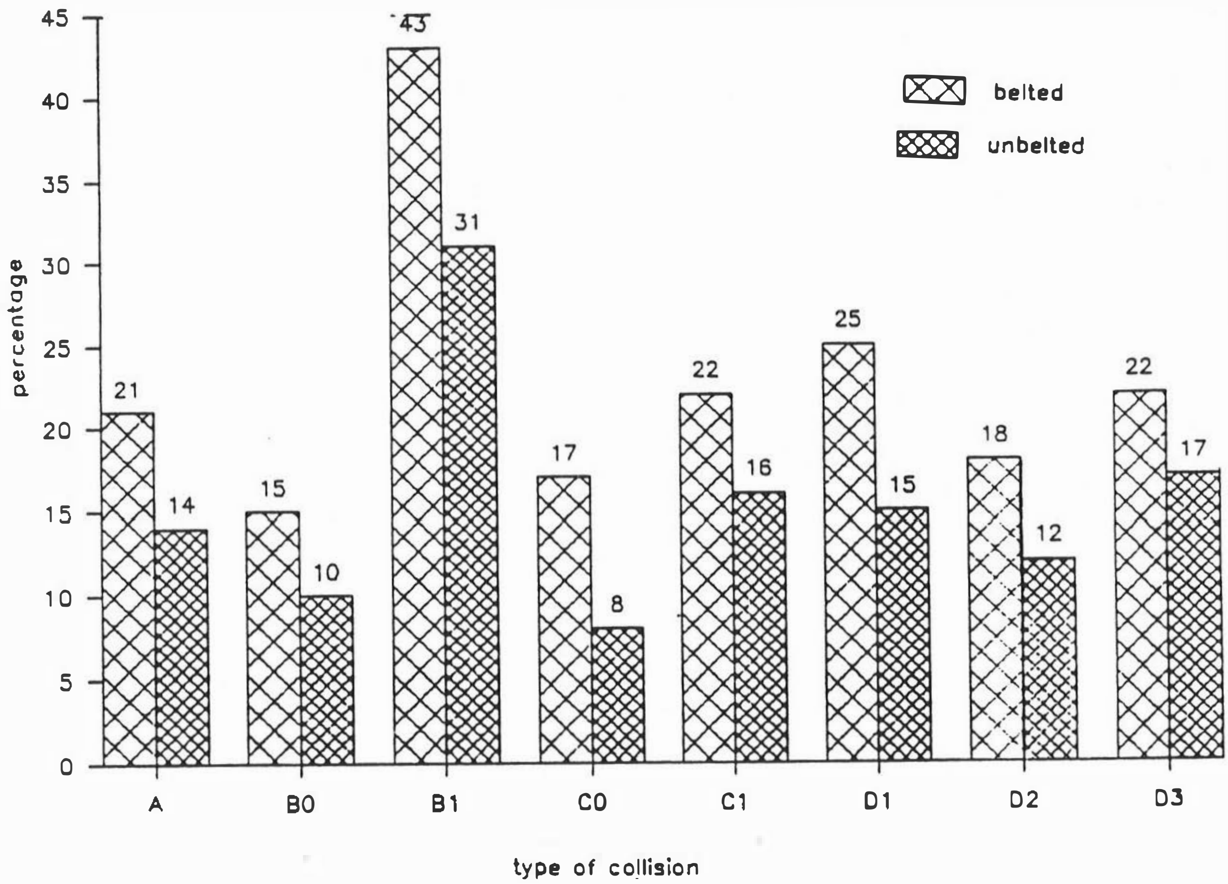
Most of the 95% confidence intervals for the relative risks do not include 1,00, i.e. certain crash situations are more likely to result in a neck sprain.

Table 3 : Relative risks for different factors

	Neck sprain	No neck sprain	Total	Relative risk	95% Confidence interval
Case :Belted	534	2 002	2 536		
Control :Unbelted	191	1 200	1 391	1,68	1,40 - 2,01
Case :Front or side impact opposite direction	427	2 749	3 176		
Control :Rear or side impact same direction	298	453	751	4,24	3,54 - 5,06
Case :≤ 50Km/hr speed limit	592	2 340	2 932	1,64	1,34 - 2,01
Control :> 50Km/hr speed limit	133	862	995		
Case :Collision with a car of similar weight	116	448	564		
Control :Collision with a car of heavier or lighter weight	609	2 754	3 363	1,17	0,94 - 1,46
Case :Collision with a car of lighter weight	252	914	1 166		
Control :Collision with a car of heavier weight	357	1 840	2 197	1,42	1,19 - 1,70

Figure 1 and Table 4 illustrate the association between seat belts and neck sprains for different stratifications of the data. Wearing a seat belt is associated with an increased chance of a neck sprain. The relative risks are fairly constant for the different strata (tests for uniformity are not significant at 5%), and hence it made sense to calculate overall relative risks and the corresponding confidence intervals using the Mantel-Haenszel estimator (Mantel N. and Haenszel W., 1959).

Figure 1: Neck sprains among belted and unbelted occupants for different types of collisions (%)



A : 2-car crash
BO : Front or side impact opposite direction
B1 : Rear or side impact same direction
CO : Collision in a > 50Km/hr speed limit
C1 : Collision in a < 50Km/hr speed limit
D1 : Collision with a car of lighter weight
02 : Collision with a car of heavier weight
03 : Collision with a car of similar weight

Table 4 : Relative risks (belted and unbelted) for different strata and overall estimates

STRATUM i	DATA (Neck sprain / no neck sprain; Belted: a_i c_i, Unbelted: b_i d_i)	Unconditional ML* Estimate of relative risk	95% confidence interval	Test of uniformity of relative risk among strata		Test of homogeneity	Mantel-Haenszel estimate of relative risk	95% confidence interval
Direction of impact								
1. Front or side impact opposite direction	308 1 707 119 1 042	1,58	1,26 - 1,98					
				0,02	NS**	4,92	1,61	1,33 - 1,95
2. Rear or side impact same direction	226 295 72 158	1,68	1,21 - 2,33					
Authorized speed limit								
1. < 50Km/hr	430 1 487 162 853	1,98	1,55 - 2,54					
				3,19	NS	5,56	1,66	1,39 - 1,99
2. > 50km/hr	104 515 29 347	2,42	1,57 - 3,73					
Vehicle weight								
1. With a car of lighter weight	193 569 59 345	1,98	1,44 - 2,73					
2. With a car of heavier weight	256 1 136 101 704	1,57	1,22 - 2,01	1,77	NS	5,57	1,66	1,39 - 1,99
3. With a car of similar weight	85 297 31 151	1,39	0,88 - 2,20					

* ML : Maximum likelyhood

** NS : Not significant at the 5% level

Finally, a loglinear model (Fienberg, 1980) was constructed to obtain an overall picture of the relationship between the factors studied above and of their relative importance. We used the $SPSS^x$ "hiloglinear" procedure to test for the hypothesis that k-way effects are zero. Since all the interaction terms between the explanatory variables and those of higher order with variable neck sprain are not significantly different from zero, a simple model containing only main effects fits the data quite well (see table 5).

Table 5 : Loglinear model

Effect	Coefficient	Std.error	Exp (2*coefficient)	Relative risk
Overall (8)	- 0,6803	0,03293	0,2565	
Seat belt $(A)_i$				
i=0 Unbelted	- 0,1153	0,02386	0,7941	1,58
i=1 Belted	0,1153	0,02386	1,2594	
Direction of impact $(B)_j$				
j=0 Front or side impact opposite direction	- 0,3678	0,02324	0,4792	4,35
j=1 Rear or side impact same direction	0,3678	0,02324	2,0867	
Authorized speed limit $(C)_k$				
k=0 > 50 km/hr	- 0,159	0,02792	0,7276	1,89
k=1 < 50 km/hr	0,159	0,02792	1,3744	
Vehicle weight $(D)_l$				
l=1 Collision with a car of lighter weight	0,0850	0,03303	1,1786	1,38
l=2 Collision with a car of heavier weight	- 0,0791	0,02993	0,8537	
l=3 Collision with a car of similar weight	- 0,0059	0,04054	0,9881	1,19

The regression-like model implied by the coefficient is:

$$\ln\left\{ n_{ijkl}(\text{neck sprain}) / n_{ijkl}(\text{no neck sprain}) \right\} = B + B(A)_i + B(B)_j + B(C)_k + B(D)_l$$

where n_{ijkl} is an expected count.

To evaluate the model in terms of odds rather than log odds, we will use the equivalent multiplicative model, with antilogs as coefficients, that is

$$n_{ijkl}(\text{neck sprain}) / n_{ijkl}(\text{no neck sprain}) = T(B)*T(A)_i*T(B)_j*T(C)_k*T(D_l)$$

Where $T(B) = \exp(2*B)$

$T(A)_i = \exp(2*B(A)_i)$

$T(B)_j = \exp(2*B(B)_j)$

$T(C)_k = \exp(2*B(C)_k)$

$T(D)_l = \exp(2*B(D)_l)$.

The model decomposes the expected odds into components where the effects (see table 5) are interpretable:

0,2565 is the overall effect

1,2594 is the seat belt effect indicating the net effect of being belted VS unbelted on sustaining a neck sprain, other things being equal. Belted injured occupants sustained a neck sprain more frequently by a factor of 1,2594.

2,0867 is the net effect of the direction of impact other things being equal. Injured occupants involved in a rear or side impact-same direction VS front or side impact opposite direction sustained a neck sprain more frequently by a factor of 2,0867.

1,3744 is the net effect of authorized speed limit other things being equal. Injured occupants involved in a crash while the speed limit is $<$ 50km/hr VS $>$ 50 km/hr sustained a neck sprain more frequently by a factor of 1,3744.

1,1786 is the effect of vehicle weight, other things being equal. Injured occupants involved in a collision with a car of lighter weight VS collision with a car of heavier or similar weight sustained a neck sprain more frequently by a factor 1,1786.

For example, consider an injured occupant wearing a seat belted involved in a rear or side impact same direction against a car of lighter weight where the speed limit is $<$ 50km/hr. For this individual the expected odds of sustaining a neck sprain VS no neck sprain given the model are:

$$n_{1111}(\text{neck sprain}) / n_{1111}(\text{no neck sprain}) = 0{,}2565*1{,}2594*2{,}0867*1{,}3744*1{,}1786 = 1{,}0919$$

Now consider an injured occupant in the same situation, but not wearing a seat belt. For this individual the expected odds of sustaining a neck sprain VS no neck sprain given the model are:

$$n_{0111}(\text{neck sprain}) / n_{0111}(\text{no neck sprain}) = 0{,}2565*0{,}7941*2{,}0867*1{,}3744*1{,}1786 = 0{,}6885$$

The ratio of these two expected odds (belted VS unbelted) yields as an estimate of relative risk 1.58 (1,0919/0,6885 = 1,2594/0,7941).

4. DISCUSSION

Our results have shown that the most serious injuries to the cervical spine, namely fractures, were more prevalent among unbelted front seat occupants. Yoganandan (1989), with a small sample size, observed that the introduction of restraints appeared to significantly reduce serious cervical spine injuries.

For the following discussion 2 points should be kept in mind:

1) only front seat occupants injured in a two car crash are considered;
2) possible biasses (under or over declaration) due to the subjective value of the neck sprain.

In our data neck sprains were more numerous among the belted occupants; the relative risk to sustain that type of injury is estimated by 1,68 (belted versus unbelted) or by 1,58 when a loglinear model is used. Salmi (1989) who studied the effect of the 1979 French Seat-belt law, found that there were fewer cervical spine injuries than expected after the law but moderate neck injuries were more frequent than expected. A similar observation was reported by Deans et al. (1987) and also by Larder et al. (1985) who stated that 15% of their sample sustained a neck injury. Larder's data come from in-depht crash investigations. Rutherford et al (1985), in his hospital-based study indicated a relative increase of 18% in neck sprains coincident with seat bel use rising from 26% to 93%. In our data 18% (725/3927) sustained a neck sprain.

We examined different types of collision and a similar result holds (Table 4): higher relative risk of sustaining a neck sprain for the belted. Table 4 shows that the unconditional ML estimate of relative risk varies from 1,30 to 2,42. The effect of increasing the frequency of neck sprains associated with seat belt wearing shows clearly in Figure 1.

These results are examined and discussed in the light of the biomechanical and medical literature on neck injury. The majority of the publications concentrates on the serious levels of injury involving fractures or neurological trauma (Larder et al. 1985, Yoganandan N. et al 1989, Sumchai et al 1988); kimematic designs do not always simulate "in vivo" conditions. Myers et al. (1989) used unembalmed cervical spines in a dynamic test environment and observed that the Hybrid III neck form was stiffer than the human and was relatively insensitive to the axis of twist.

In a frontal impact, the asymmetric geometry of the lap/shoulder belt provokes a rotation-inclination motion of the thorax-head-neck system toward the left for drivers and toward the right for front seat passengers. In addition, when the body is held down by the safety belt the torso is restrained, but the safety belt allows a forward-backward motion of the head due to sudden acceleration-deceleration events which may cause torquing of the neck (Chabannes et al. 1985).

Huston and King (1988) measured the effects of the asymmetric belt geometry upon human responses. The analysis used the UCIN-CRASH, a vehicle-occupant, crash-victim simulation computer code. The results show that the asymmetric geometry of the restraint leads to a head twist.

Neck sprains involve mostly soft tissues of the head-neck complex. These injuries have significant societal implications (Yoganandan et al 1989 p. 240). Chronic pain and long term disability resulting from motor vehicle accidents has been discussed by Dooley (1986 SAE) who quotes Chapman and Decker in defining chronic pain as a "socio-economic disease". Dooley states that a chronic pain problem is often associated with depression, anxiety somatic preoccupations, passivity, grossly restricted activity, anger and even drug addiction. Laberge-Nadeau et al. (1988) reported that the single diagnostic of neck sprain (ICD-9:847.0) counted for 11% of the study population compared to other main diagnosis of car crash victims receiving long term revenue compensation from the Régie de l'Assurance automobile du Québec. The RAAQ is a governement insurance company that covers all injured road victims of the province. Each victim received an average of $ 8 055 at the time the sample was taken (3 to 6 years of a retrospective follow-up). Larder et al. (1985) report that 40% of their cases of neck injuries had pain lasting at least one month and 8% had symptoms lasting for longer that 6 months. In a small sample (137 patients), Deans et al. (1987) contacted injured patients involved in a car crash by questionnaire administered between 1 and 2 years after their accident: 62% complained of pain in the neck following their accident. In 26% the pain lasted more than a year; 23% experienced occasional pain and 3,7% severe continuous pain. These injuries are not a negligeable problem, it can handicap a person for a long time.

5. CONCLUSION

The result of our research and of others raises several questions about neck injury protection. Despite the fact that the belted front passengers are more protected from severe neck injuries, would there be measures to prevent neck sprains?

In addition, other hypotheses may be important to verify, such as that asking whether the air bags combined with a better seat-belt support would help to prevent neck injuries. Would better head rests protect better the neck extension and prevent a portion of the neck sprains?

Further studies on real crashes and laboratory tests must therefore be carried out in order to clarify the nature of such an injury which is presently unclear and which presents a special problem for the victims and for the automotive insurance compensation.

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