Crash severity and neck strain in car occupants

Ryan GA,[1] Moore VM,[2] Dolinis J [3]
National Health and Medical Research Council Road Accident Research Unit,
University of Adelaide, South Australia

Taylor GW,
Wayville Physical Care Centre, Adelaide, South Australia

Abstract

There has been considerable debate as to the relationship between the severity of a crash and the severity and persistence of subsequent symptoms and signs of neck strain. This study was designed to examine relationships between factors related to the crash, the initial severity of neck strain and its persistence six months after the impact. Thirty-two individuals with neck strain following a car crash, drawn from physiotherapy and general practices in Adelaide, South Australia, were interviewed and underwent a physical examination soon after the crash and again after six months. Each case vehicle and the site of each crash was inspected and the crash events reconstructed. The severity of the crash was assessed by measurement of maximum residual deformation and estimation of velocity change. Five measures of neck strain severity were used: number of body regions with symptoms, number of positive responses to palpation, cervical range of motion, subject's own rating on an analogue pain scale, and a severity rating by the examiner. In 22 cases the impact was from the rear, the remainder were from the front or the side. Neck strain was observed in crashes of low severity, six cases having a velocity change of less than 10 km/h and eight cases a maximum residual deformation of less than 50 mm. For rear impacts, maximum residual deformation and velocity change were positively associated with measures of neck strain severity. Six months after the impact, 19 (66%) of the 29 subjects available for follow-up still had evidence of injury. There was no statistically significant association between either measure of crash severity and persistence of neck strain at six months. Subjects who were aware of the impending collision had less severe symptoms and signs initially and were much less likely to experience persisting problems. This study has shown that neck strain can occur at low levels of crash severity and that there is a correlation between crash severity and initial severity of neck strain. A study of greater statistical power would be required to investigate fully the relationship between crash severity and the persistence of neck strain.

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[1] Currently at Road Accident Prevention Research Unit, University of Western Australia

[2] Currently at Department of Community Medicine, University of Adelaide, South Australia

[3] Currently at National Injury Surveillance Unit, Adelaide, South Australia

Introduction

Neck strain is one of the most common injuries resulting from car crashes. For example, neck strain accounts for over 40% of all injuries sustained in motor vehicle crashes in Japan [Emori and Horiguchi, 1989]. In the Canadian province of Quebec, around one quarter of injured persons with car accident insurance claims during 1987 had a neck strain injury [Maag et al., 1993]. Up to 30% of car occupants may be expected to have signs and symptoms of neck strain when examined soon after the crash [Larder et al., 1985; Deans et al., 1987] while in the longer term some 60% report experience of neck pain [Deans et al., 1987].

Characteristic symptoms are aching pain and muscle spasm in the neck, stiffness and restriction of neck movement. Accompanying these may be headache, sensory deficits in the upper extremities, nausea and dysphagia [Pennie and Agambar, 1991]. The acute condition usually stabilises within a few weeks [Deans et al., 1987; Maimaris et al., 1988]. A significant proportion of people go on to suffer chronic problems however, and a number of recent studies have documented this. In a group of patients from a primary care setting, 27% had symptoms six months after the crash [Radanov et al., 1991]. Amongst a series of medico-legal cases, 18% remained symptomatic at six months, reducing slightly to 15% at one year [Pearce, 1989]. Where cases attended hospital, the proportion with chronic injury is generally greater, as illustrated in the follow-up studies of Norris and Watt (1983) and Maimaris et al. (1988) in which the proportions not fully recovered after one year and after two years, respectively, were 69% and 33%.

In spite of the familiarity of the condition, its legitimacy as an injury remains contentious. In part this is due to the subjective nature of an individual's pain experience, coupled with the difficulty of detecting objective pathological signs that offer a reliable prognosis [Gargan and Bannister, 1990]. Consequently, alternative explanations for the advent and continued presence of symptoms have been suggested, including financial motivation and other psychosocial factors [Awerbuch, 1992; Merskey, 1984; Mendelson, 1982]. Recent research has not offered support for these hypotheses. A number of studies have shown that individuals continue to experience symptoms after settlement of compensation claims [Watkinson et al., 1991; Gargan and Bannister, 1990; Hohl, 1974] and one study found no evidence of any influence of a large set of psychosocial variables on recovery [Radanov et al., 1991].

Crash-related factors are recognised as being of fundamental importance in understanding the mechanisms by which neck injury occurs, and should therefore also be considered as potentially important predictors of injury severity and duration. Variables which have been examined include seat-back and head-restraint properties, occupant position in vehicle, orientation of head, and vehicle mass (e.g. Svensson et al., 1993; Ono and Kanno, 1993;

Maimaris et al., 1988; Deans et al., 1987; Norris and Watt, 1983). To date, influences of these variables on clinical outcomes have not been consistently demonstrated.

The severity of the crash has been recognised as a likely determinant of initial injury severity and outcome [Pennie and Agambar, 1991; Radanov et al., 1991] but few studies have tried to examine these relationships using sound engineering methods. A suggestive result was obtained in early work of Hohl (1974), in that crashes which resulted in at least one seat being damaged or torn from its track were found to be most likely to produce the most severe initial symptoms. A recent study by Olsson et al. (1990) contained a much more sophisticated assessment of crash severity: for 26 Volvos involved in rear-end collisions, measurements were made of the maximum residual deformation and were translated into energy equivalent barrier speeds using data from crash barrier tests. While there was no evidence of an overall association between duration of symptoms and energy equivalent barrier speed, for those cases where a side beam of the car had been struck or deformed, there was evidence of a correlation between duration of neck injury and the square of the maximum residual deformation. Ono and Kanno (1993) performed simulated low-speed rear-end collision experiments with volunteers to clarify neck injury mechanisms. They found that the bending moment acting on the neck was approximately proportional to sled impact speed (and thus to crash severity) but this relationship was sensitive to differences in sitting posture and the relative position of the head-restraint.

The aim of this study was to examine relationships between factors related to the crash, particularly crash severity, and both the initial severity of neck strain and its persistence six months after the impact.

Method

Study participants were volunteers drawn from a group of physiotherapy and general medical practices in Adelaide, South Australia, over the period May to August 1992. In order to be eligible, subjects were required to be at least 15 years of age, to have recently sustained a neck strain as a result of being a car occupant during a crash, and to have had no other significant injuries. After obtaining verbal consent from those who met these criteria, details were sought about the crash events such as place, time, date and the current locations of the vehicles involved.

Each subject's vehicle was examined and the site of the crash inspected. Where possible, any other vehicles involved in the crash were also examined. From these investigations, crash events were reconstructed, enabling the severity of the crash to be measured in terms of two parameters: the maximum residual deformation of the subject's vehicle and the velocity change

(delta-V) experienced by that vehicle. The Crash 3 program [U.S. Department of Transportation, 1981] was used to calculate velocity change based upon vehicle damage profile measurements obtained during the crash investigation.

Subjects were interviewed and underwent a physical examination by a manipulative physiotherapist soon after the crash and again six months later. During the first interview, details of the crash circumstances were sought, including position in vehicle, orientation of the head during the crash, and whether or not the subject had been aware of the impending collision. The second interview served to ascertain the course of the injury over time and the nature and amount of treatment received. On both occasions the subject was asked to rate the amount of pain currently being experienced on a scale from zero to ten, with the extremes representing no pain and intense pain, respectively. At each of the two examinations the physiotherapist recorded the nature and locations of symptoms, areas of tenderness to palpation, evidence of neurological impairment, and the range of motion of the neck in forward flexion, extension, left and right lateral flexion, and left and right rotation. Upon completion of each interview and physical examination, the physiotherapist classified the subject's injury state as either symptom free, minor, moderate, or severe.

Each measure of initial injury severity (i.e. obtained soon after the crash) was tested for associations with the two measures of crash severity using Spearman's correlation coefficients. For associations between injury severity and other crash-related factors, the Mann-Whitney U-test was used. In order to examine relationships between crash-related factors and injury status at six months, subjects were classified as either recovered, meaning that no signs or symptoms were evident, or as continuing to have signs or symptoms of neck strain. Associations between this measure of injury status and predictor variables were assessed using odds ratios. Exact confidence intervals [Mehta et al., 1985] were calculated using the Epi Info program [Dean et al., 1990]. The criterion level for statistical significance in all tests of association was set at 5%; where odds ratios are presented, statistical significance is indicated by a confidence interval that does not contain the value one.

Results

Thirty-two subjects participated in the study initially. As subjects were volunteers, it is not known what proportion of eligible individuals this sample represents. Follow-up information on injury status at six months was obtained from 29 (91%) of those in the initial sample; of the remainder, one subject could not be located, one refused further participation, and a third had to be excluded due to involvement in another crash.

The initial sample consisted of 14 males with a median age of 43 years (range 21 to 69 years) and 18 females with a median age of 28 years (range 15 to 52 years). The follow-up sample had similar age and sex characteristics. It consisted of 12 males with a median age of 48 years (range 21 to 69 years) and 17 females with a median age of 28 years (range 15 to 39 years).

All subjects were wearing a seat belt, and most had been the driver of the car they occupied. Of the initial sample, 13 subjects (41%) said that they were aware of the impending collision, and 20 (63%) reported looking straight ahead at the moment of impact. The crashes all occurred on main roads in the Adelaide metropolitan area. In 22 cases the impact was from the rear, while the remainder were from the front or the side. Most of the crashes were relatively minor, with six cases having a velocity change of less than 10 km/h and eight cases having a maximum residual deformation of less than 50 mm (Table 1).

Table 1: Crash characteristics

	n	%
Impact direction		
rear	22	68.8
front	5	15.6
side	4	12.5
not known	1	3.1
Velocity change (delta-V)		
0 - 9 km/h	6	18.7
10 - 19 km/h	16	50.0
≥ 20 km/h	3	9.4
not known	7	21.9
Maximum deformation		
0 - 49 mm	8	25.0
50 - 99 mm	7	21.9
≥ 100 mm	12	37.5
not known	5	15.6
Vehicle mass		
< 950 kg	4	12.5
950 - 1399 kg	21	65.7
≥ 1400 kg	6	18.7
not known	1	3.1

Predictors of initial injury severity

Five measures of injury severity were assessed (as described in the Method): number of body regions with symptoms, number of positive responses to palpation, cervical range of motion, subject's own rating on an analogue pain scale, and a severity rating by the examining physiotherapist. There were no associations between any of these measures of injury severity and either the subject's position in the vehicle, the orientation of the head, the height of the head relative to the position of the head rest, the impact direction, or the vehicle mass.

Initial injury severity and awareness of the impending collision were associated. Those subjects who reported that they were aware showed a greater range of neck motion in each of the tested movements, the differences being statistically significant in four out of the six directions (Table 2). Furthermore, the aware group displayed half the number of responses to palpation as the non-aware group. These differences were unlikely to be due to confounding by age, sex, or crash severity, since the two groups had similar distributions of these factors.

Table 2: Injury severity and awareness of collision (median values)

Injury severity	Aware of impending collision		p-value*
	Yes	No	
regions with symptoms	4	4	0.58
positive responses to palpation	3	6	0.07
flexion	58°	30°	0.01
extension	48°	35°	0.03
left lateral flexion	31°	21°	0.18
right lateral flexion	32°	21°	0.02
left rotation	55°	51°	0.32
right rotation	64°	42°	0.02
subject's severity rating	5	5	0.34
examiner's severity rating	moderate	moderate	0.51

* Probability value associated with Mann-Whitney U test statistic

With regard to crash severity, there was a statistically significant positive association between maximum deformation and both the subject's and examiner's assessment of initial injury severity (Table 3). None of the other correlations between crash severity and injury severity achieved statistical significance.

The analysis was repeated for the 22 rear impacts in order to remove variation in the measures of crash severity that were due to the directional dependence of vehicle crush properties. In this homogeneous group of crashes, the correlations between crash severity and initial injury severity were generally strengthened. Both maximum residual deformation and velocity change were significantly associated with the subject's and examiner's rating of injury severity. Velocity change was significantly correlated with the number of body regions in which symptoms were present, while the correlation between maximum residual deformation and flexion became significant, and the other cervical range of movement correlations all approached significance at the 5% level (Table 4).

Table 3: Correlation between crash severity and injury severity - all impacts (Spearman coefficients)

Injury severity	Crash severity	
	Maximum deformation	**Velocity change**
regions with symptoms	0.13	0.28
positive responses to palpation	0.12	0.12
flexion	- 0.27	- 0.18
extension	- 0.31	- 0.19
left lateral flexion	- 0.28	0.13
right lateral flexion	- 0.18	0.07
left rotation	- 0.23	- 0.22
right rotation	- 0.19	0.01
subject's severity rating	0.66*	0.35
examiner's severity rating	0.51*	0.36

* $p<0.05$

Table 4: Correlation between crash severity and injury severity - rear impacts (Spearman coefficients)

Injury severity	Crash severity	
	Maximum deformation	**Velocity change**
regions with symptoms	0.50	0.63*
positive responses to palpation	0.09	0.13
flexion	- 0.52*	- 0.23
extension	- 0.48	- 0.43
left lateral flexion	- 0.44	0.04
right lateral flexion	- 0.47	- 0.27
left rotation	- 0.42	- 0.27
right rotation	- 0.27	- 0.27
subject's severity rating	0.63*	0.58*
examiner's severity rating	0.58*	0.75*

* $p<0.05$

Factors associated with injury status at six months

Six months after the impact, 19 (66%) of the 29 subjects available for follow-up still had evidence of injury and were classified as continuing to have a neck strain injury, while the other 10 were deemed to have recovered.

Relationships between a number of crash-related factors and injury status at six months were examined. Injury status at six months was not associated with impact direction, the subject's head orientation or with either measure of crash severity. Subjects who were not aware of the impending collision were at a greatly increased risk of experiencing persisting neck strain, compared with those who were aware (odds ratio = 15.0; 95% confidence limits: 1.8, 178).

Discussion

Subjects participating in this study were self-selected. This could bias the results if the relationships under examination are different for volunteers and non-volunteers. The use of volunteers could conceivably weaken correlations between injury severity and crash severity if

volunteers tend to exaggerate minor injuries, but it is difficult to see how this choice of sample might lead to positive bias, or account for an association between injury severity and awareness. Therefore, it is considered unlikely that the use of volunteers produced or inflated the relationships found.

This study has shown that neck strain can result from quite minor impacts: in a few cases there was almost no vehicle damage. There were cases of injury following front and side impacts as well as rear-end collisions, confirming that neck strain can occur as a result of impacts from all directions.

It should be noted that owing to the small sample size, which was restricted by the intensive effort required to collect the data, the study had limited power to detect small to moderate effects. Nonetheless, an influence of crash severity on initial injury severity was evident, particularly for rear impacts. This has been explored in more detail in Ryan et al. (1993). Six months after the crash, associations between crash severity variables and injury status were no longer statistically significant, although the data suggest that subjects who experienced greater crash severity, as assessed through change in vehicle velocity, were more likely not to have recovered than subjects involved in crashes of lesser severity. The absence of associations after six months may be due to some dilution of the relationship by other factors affecting recovery, hence reducing the probability of an association being detected in this study of only limited power.

Awareness of the impending collision was associated with the state of the injury both initially and after six months. There was a mitigating effect on initial injury severity, with aware subjects tending to have fewer positive responses to palpation and a greater range of neck movement than those subjects who were unaware. Awareness was also a strong predictor of injury status at six months, with subjects who were unaware being 15 times more likely to have a persisting neck strain than those who were aware. Some errors might have been made in the reporting of awareness, but such misclassification would have a conservative influence on any associations. The findings are unlikely to have arisen due to confounding, as the aware and unaware groups had similar distributions of crash severity, age, sex, and previous history of neck injury. It has previously been suggested that awareness of the impending collision may ameliorate the severity of the injury through preparing the neck muscles to resist extension beyond the normal range [Selecki, 1984; Cailliet, 1981] although the effect has not previously been demonstrated outside of an experimental situation (e.g. Ono and Kanno, 1993). This observation is biologically plausible and could prove to be a valuable indication of the likely outcome of a neck strain injury.

The results of this study indicate that crash severity and awareness of the impending collision play a role in the occurrence and duration of neck strain injury. The findings are compatible with a model linking the mechanical input to the neck from the impact with the resulting soft tissue injury, suggesting that the condition has an organic basis rather than psychosocial origins.

Conclusion

Neck strain can occur in individuals involved in crashes of relatively low severity. Crash severity is positively correlated with initial injury severity but further work is needed to determine its influence in the longer term. Awareness of the impending collision appears to have a mitigating effect on initial injury severity, and there is also evidence for a strong association between lack of awareness and persistence of neck strain symptoms for at least six months following the crash. Replication of these results should be sought in a larger sample.

Acknowledgements

This research was supported by a grant from the Motor Accidents Authority of New South Wales and the grant to the NHMRC Road Accident Research Unit from the National Health and Medical Research Council. We thank the participating centres of the Physical Care Group in Adelaide and the study subjects for their co-operation.

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