THE INJURY SEVERITY RATE DIFFERENCES IN PASSENGER CARS AND PICK UP TRUCKS RELATED TWO VEHICLE INVOLVED MOTOR VEHICLE CRASHES IN BRITISH COLUMBIA, CANADA

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The effect of large vehicle involvement on motor vehicle crash (MVC) rates and severity has long been a concern in MVC analysis literature. Injuries in drivers and occupants are related to several key factors: the mass of the case vehicle and mass of its collision partner and speed of case vehicle and collision partner at the time of the crash. Objective: To evaluate the relative risk of injury occurrence in collisions between picks up trucks (PU) and passenger sedan cars (PS). Methods: Data from the Insurance Corporation of British Columbia (ICBC) crash data base was used to determine MVC rates and injury occurrence. Descriptive characteristics of the injury location and injury type were analyzed comparing the Odds Ratios and chi-squares. Results: PS occupants received more injuries; Odds Ratio was 2.49 (95% confidence interval: 2.15-2.88). Conclusion: Occupants in PS which collide with PU were at twice the risk of injuries. Concussion, whiplash, lacerations and abrasion were more frequent in PS drivers and occupants than in PU drivers and occupants. Overall, PS drivers/occupants experienced greater injuries than PU drivers/occupants in PU-PS collisions. In this paper, results are shown as odds ratios comparing occupants injuries in PS (case group) with occupant injuries in PU (control group).

Key Words: Passenger sedan cars, Pick up trucks, Vehicle fleet, Vehicle mismatch crashes, Injury severity

1. INTRODUCTION

Worldwide, 3,000 people are killed and 30,000 are seriously injured on roads every day[1]. Road-traffic injuries are predicted to rise by 2020 to third place in the global burden of disease[2]. Evidence needs to be developed to direct policy to eliminate unnecessary injuries related to motor vehicle crashes in the world. The identification of effective strategies for the prevention of traffic related injuries is of global health importance.

The main injury risks for car occupants arise from the way vehicles interact with each other and with the roadside in frontal and side-impact crashes. Chief determinants for the degree of severity of injuries in motor vehicle collisions are vehicle size and weight. The European commission has stated that if all cars were designed to be equal in standard to the best car currently available in each class, then an estimated 50% of all fatal and disabling injuries could be avoided[3]. A recent North American research has shown that replacing light trucks with cars of the same mass would save more than 1,000 lives a year[4].

Transport Canada unveiled a national road safety strategy entitled "Road Safety Vision 2010,"[5] which aims to achieve the safest roads in the world by 2010. The national targets calls for a 30% decrease in the average numbers of road users killed or seriously injured during the 2008-2010 period (compared to 1996-2001 data). To meet this new target, continued efforts must be made to identify the new problem areas of traffic safety at the national, provincial and municipal levels.

As occupant protection offered by new passenger vehicles has improved, there has been growing concern about the harm that some vehicle designs may inflict on occupant of other vehicles with which they collide. Studies have shown that proliferation of large sport utility vehicles (SUVs) and pickup trucks which are more dangerous to occupants of other vehicles in crashes. It is highlighted as a chief obstacle in further reduction of motor vehicle crash related morbidity and mortality in North America[6]. In two vehicle collisions, the protection of all occupants in the subject and the other vehicle should be considered. Compatibility means that passenger vehicles of disparate size provide an equal level of occupant protection in two vehicle collisions[7,8]. Vehicle mismatch is defined as design differences between vehicle types which result in disproportionate damage patterns to the vehicles involved in a collision; these design differences include weight, frame height, and stiffness. This is also known as crash incompatibility. The damage patterns can result in a violation of the structural integrity of the passenger compartment resulting in increased risk of serious injury or death to the occupants[8,9].

The Canadian as well as British Columbia vehicle fleet differs in mass, geometry stiffness and many other parameters. These differences are consequences of different design objectives for these vehicles and result from consumer demand, environmental and safety considerations. The following statistics on vehicle ownership shows us new emerging trends in vehicle fleet in both Canada and the British Columbia.

Registration of Light Trucks (LT) in Canadian vehicle fleet has been increased from 2,650,799 in 1990 to 4,012,370 in 2001. Significantly the LT (Pickup trucks and SUVs) ownership has been increased by 51.3% since 1990.By comparison; small car ownership has been moderately increased by 7.9% from 5,795,765 in 1990 to 6,254,224 in 2001. Registration of LT in British Columbia vehicle fleet has been increased from 340,549 in 1990 to 636,631 in 2001. Significantly the LT ownership has been increased by 86.9% since 1990. By comparison, small car ownership has been increased by 17.9% from 550,495 in 1990 to 747,654 in 2001. It is estimated that utility vehicles accounted for approximately 40% present British Columbia vehicle fleet. Increasing utility vehicle ownership is in Canada and British Columbia which produce crash incompatibilities when they impact cars, represent a substantial threat to the ability of the present set of safety devises to continue maintain a low injury, low complication and reduced injury profile after MVC[7].

In addition proportion of LT sales, compared with passenger cars has approximately doubled during the last decade to nearly 90%. Furthermore, of all new Canadian vehicle sales in 1997, three of the top four selling models belong to the LT class[7,10,11]. Not only have LT captured an increasing share of the market, but also their usage characteristics have changed significantly since their initial introduction into the vehicle fleet. They are being used increasingly more as passenger vehicles since the demographics of their owners have changed. PU are being used more for the combined conveyance of passengers (through the inclusion of small passenger compartments behind primary setting) in addition to cargo[7]. To environmental and safety advocates, the extension of the auto ownership from sedan cars to pickup trucks is a worrisome development[6-8].

Disparity in size of the two vehicles, especially when the struck vehicle is smaller and lighter, is almost a consistent risk factor for occupant injury[7,12]. Impact and injury analysis document a negative correlation between vehicle mass and injury severity in car-to-car crashes[13, 14].

The fatality rate for 900-kg passenger cars is 50% greater than the fatality rate for 1,800-kg passenger cars. Occupants of smaller cars appear to be at greater risk than larger car occupants in many types of collision scenarios[15, 16]. It is reasonable to assume that small car occupants will be more at risk in collisions that display certain kinds of mass-related properties[7,13].

Kahane[17] estimates that a 100 pound reduction in the average weight of light trucks, defined as PU, vans and SUVs, results in a reduction of 40 fatalities per year in US. Importantly, Kahane[17] shows that decline of 100 pounds in the average weight of the typical passenger car results in an estimated increase of 302 more fatalities per year. The results also indicate that 80% of the injuries/ fatalities associated with car-light truck collisions are occupants of passenger cars. The Insurance Institute for Highway Safety estimates that the relative risk of death among occupants of passenger cars that are involved in crashes with light trucks is approximately 47:1 compared to crashes involving similar size vehicles[8]. There is evidence that car size does play a role in two vehicle crashes. The strongest is that when cars of same mass crash into each other fatality and injury risk is lower for two heavier cars crashing into each other than for two lighter cars crashing in to each other[13,18-20].

Vehicle mismatch crashes should be recognized as a risk factor for injuries. As a PU and SUVs continue to proliferate the national and provincial vehicle flees, there should be a high priority in conducting MVC studies on the impact of this trend on injury rates and crash incidence rates. In this study we have attempted to examine the injury severity rate difference in two vehicle crashes that involved PU-PS in British Columbia during 2002.

2. DATA AND METHODS

We obtained BC MVC data from Insurance Corporation of British Columbia[21]. This database provides information on driver and occupant/rider characteristics and vehicle characteristics. MVC data for 2002 used in this study to investigate vehicle incompatibility and estimate the injury rate comparisons between PU-PS involved collisions in BC. For the purpose of this review, mismatch collisions between PS (defined as vehicles on car frames) and PU (defined as vehicles on truck frames) has been selected. After applying the exclusion criteria to the initial data set, 953 of two vehicle PU-PS related crashes (1,906 vehicles) were identified. In addition 2,719 drivers and occupants involved 1,321 injuries were analyzed to estimate the injury rate difference.

Analyses were performed on crashes involving PS-PU vehicles. Odds Ratio (OR) with 95% Confidence Intervals (CI) were calculated to determine the magnitude of injury severity in vehicle mismatch crashes. In this paper, results are shown as odds ratios comparing occupants injuries in PS (case group) with occupant injuries in PU (control group).

3. RESULTS

Drivers and crash characteristics-age of the driver

PU drivers differed greatly in their gender distribution, 80% of the total being males. In gender variation in PS drivers were 1:1 (51 % male and 49% females). The mean age was 40.8 (SD=16.8) years for PU drivers and 43.3 (SD=20.1) years for PS drivers. In comparison, average PU drivers were younger than the PS drivers.

Crash characteristics

75% of PU-PS crashes occurred between 8 a.m. and 6 p.m. Accordingly majority of crashes were distributed with peaks between 8 a.m. and 5 p.m., and (15%), occurred between 6 p.m. and 10 p.m.

PU-PS crash related environmental factors

Environmental factors and, in particular unsafe conditions also are known to result in MVCs and related injury. 72% of PU-PS involved MVCs reported in daylight, 12% in dark with some illumination and 7% with full illumination. It is common knowledge that rain, sleet or snow not only reduces visibility but also contributes to unsafe road conditions. Most of the MVCs occur in dry weather conditions (53%) while 17% in wet weather conditions and few (4%) reported when it was snowing.

PU-PS crashes and driver errors

Many PU-PS crashes accounted to driving errors such as failing to yield the right-of-way (27%), driving without due care (17%) disobeying traffic signs (13%) unsafe speed (7%) and alcohol involvement (4%). Overall driver errors was concern PU drivers contributed more PU-PS crashes (54%) while small vehicle drivers' driver errors were contributed to 46% of PU-PS crashes in 2002.

PU-PS crashes and restraint use

Overall seat belt use: A seatbelt was worn by 84% of PU occupants and drivers compared with 87% of car drivers and occupants. Moreover, 4% of PU drivers and occupants did not wear seat belts compared with 1.3% of PS drivers and occupants. For the other cases, the information on seatbelt wearing was unknown. Many studies have indicated that crash related injury rates can be differing by rate of seat belt use by vehicle occupants. Accordingly we have compared seat belt wearing rates in PU-PS injury group with non injury group as follows:

Table 1 Comparison of restraint use in injury group versus non injury group in PU-PS crashes

RESTRAINT USE	INJURY GROUP		NON INJURY GROUP	
	PU	PS	PU	PS
LAP AND HARNESS	82%	86%	77%	84%
LAP BELT ONLY	6%	5%	4%	4%
NO RESTRAINT USED	7%	4%	2%	1%
UNKNOWN	5%	5%	17%	11%
Total	100%	100%	100%	100%

X^2 test-17.54, $P < 0.05$

As shown in the Table 1 seat belt wearing rates for both PS and PU drivers and occupants were higher. Seatbelt use is a protective factor. However 88% belted PU drivers and occupants and 91% belted PS drivers and occupants were injured, whereas among injured only 7% of PU drivers and occupants and 4% of PS drivers and occupants were not using the seat belts at the time of crash. 82% of the PU, 88% of the car occupants in non injury group has wearing the seat belts. The percentage of missing values for this variable was low-5%, 5%, 17% and 11% respectively. For this reason it was not possible to conclude that there was an association between injury differences in rates and seat belt wearing, but equally a high rate of seat belt use among PU occupants and PS occupants might have explained that the particular injury types in small vehicles cannot be reduced wearing seat belts alone in PU-PS crashes. In other words protective nature of the seat belts can be reduced to a greater extent in small vehicles in vehicle incompatible crashes. This further supports findings in three earlier studies[13,18,22] that safety belt effectiveness depends systematically on different vehicle size.

The use of safety belts is the single most effective means of reducing fatal and nonfatal injuries in motor vehicle crashes. In all types of crashes, manual lap-shoulder belts are approximately 45% effective in reducing fatalities in passenger cars and 60% effective in light trucks[22, 23]. They are estimated to reduce the risk of serious injury to the head, chest, and extremities by 50% to 83%[23]. Lap belts alone, used most often by rear seat occupants, are estimated to be 17% to 58% effective in preventing death compared with no restraints[17, 18, 22].

Table 2 Types of injury that occupant sustained in PU-PS crashes

TYPE OF INJURY	PS	PU	CRUDE OR*	95% CI*
ABRASION	62	27	2.6	1.65,4.11
BRUISES	163	107	1.72	1.34,2.22
WHIPLASH	316	128	2.80	2.25,3.47
CONCUSSION	18	5	4.08	1.79,6.99
LACERATIONS	40	23	1.97	1.17,3.30
FRACTURE	26	7	4.21	1.82,9.73
OTHER	43	14	4.02	2.44,6.64
TOTAL INJURIES	696	317	2.49	2.15,2.88
No Injuries	1799	2041		

* OR, odds ratio; CI, confidence interval.

Types of injuries

As shown in the Tables 2 and 3 above, PS drivers and occupants were received more injuries than PU drivers and occupants (OR, 2.49; 95% CI, 2.15-2.88). Car occupants received more abrasion injuries; odds ratio was 2.6 (95% CI: 1.65, 4.11) Fractures; OR was 4.21 (95% CI: 1.82, 9.73) lacerations; OR was 1.97 (95% CI: 1.17, 3.30) whiplash; (OR 2.80; 95% CI 2.25, 3.47) and concussions; OR was 4.08 (95% CI: 1.51, 11.02). Concussion, whiplash, lacerations and abrasion were more frequent in PS drivers and occupants than in PU drivers and occupants.

Injury location

Upper torso (OR, 3.20, CI 2.07, 4.94); head face nose eye (OR 2.21, CI 1.64, 2.98) neck (OR, 2.68, CI 2.12, 3.40) entire body (OR 4.53, CI 1.85, 11.12) upper extremity (OR 2.29, CI 1.55,3.39) injuries were more frequent and significant in PS drivers and occupants than PU drivers and occupants.

Data using crash dummies suggest that MVCs involving passenger cars (PSs) , Light Trucks (LTs) produce more severe injuries than those involving two Passenger Cars (PSvPS) or two Light Trucks (LTvLT). Research done in this area have shown that how a bullet vehicle, with a high front bumper region and a raised bonnet with very stiff facial, intrudes significantly into the soft section of a sedan shape car resulting in severe head and chest trauma[8].

Further analysis of BC vehicle mismatch crash data revealed that the number of injured drivers and passengers per 1,000 crashes differed substantially by vehicle type. When a PU collides with a PS, occupants in the PS injured at a rate of 351 per 1,000 crashes. By comparison, PU vehicles occupants injured at a rate of 160 per 1,000 crashes. When a PU collides with a PS, occupants

Table 3 Comparison of injury locations that occupants sustained in PU-PS crashes

INJURY LOCATION	PS	PU	CRUDE OR*	95% CI*
UPPER EXTREMITY (elbow, lower arm, hand, shoulder/upper arm	79	39	2.29	1.55, 3.39
LOWER EXTREMITY (hip/upper leg, knee, lower leg foot)	42	28	1.70	1.05,2.75
UPPER TORSO	79	28	3.20	2.07,4.94
LOWER TORSO (abdomen, pelvis, back)	86	41	2.37	1.63,3.47
ENTIRE BODY	24	6	4.53	1.85,11.12
HEAD, FACE, NOSE, EYE	135	69	2.21	1.64,2.98
NECK	251	106	2.68	2.12,3.40
TOTAL INJURIES	696	317	2.49	2.15,2.88
No Injuries	1799	2041		

* OR, odds ratio; CI, confidence interval.

in the PS injured at a rate of 393 per 1,000 vehicles. By comparison, PU vehicles occupants injured at a rate of 234 per 1,000 vehicles. Injuries per 1,000 motor vehicle drivers and occupants are higher in PC occupants (270 per 1,000 occupants) when compared to PU drivers and occupants injury rates (184 per 1,000 occupants) in PU-PS related crashes.

4. DISCUSSION

The impact that LT have on crash severity has long been a concern in the MVC analysis literature. Previous studies on PU-PS related crashes have confirmed that these two categories of vehicles are incompatible from a design point-of-view[23-26]. Furthermore a recent studies[9,17, 20, 22-27] have shown that a disproportionate number of the injuries in PU-PS crashes are incurred by the PS's drivers and occupants. A comparison of PU and PS collisions in the previous literature reveals that the PU is more aggressive than PS for a number of reasons including their greater weight, stiffer structure, and higher ride height[4]. Many PU models have an inherently higher centre of gravity, larger masses, and stiffer chassis. These features place occupants of passenger cars at a disadvantage in vehicle mismatch crashes. PU and SUVs have the highest ride height with an average rocker panel height of 390 mm. In contrast, subcompact cars have the lowest-riding height with an average rocker panel height of 175 mm. PU and SUVs ride almost 200 mm higher than mid-sized cars – a geometric incompatibility that would readily permit the SUV to override any side structure in a car and directly strike the car occupant[7].

Our results not only corroborate the previous reports[7,8,11,23-29] but also support the proposition that occupants in PS are more than two times as likely to be injured as drivers or passengers in PU. New large size vehicles are designed to promote increased safety to their own occupants while, with little attention to the safety of small vehicle users, pedestrian and bikers. This sense of personal security may possibly lead to greater risk-taking by PU drivers[30-32].

5. CONCLUSIONS

In Canada, passenger vehicles are shifting rapidly from a fleet populated primarily by cars to a fleet dominated by light trucks and vans (LTs). Because LTs are heavier, stiffer, and geometrically more blunt than passenger cars, they pose a dramatically different type of threat to car occupants. In conclusion, vehicle mismatch is associated with serious injury in automotive crashes. The injury risk for PS occupant is greater than the risk for PU occupant in two-vehicle crashes. The injuries identified in this study support the need for re-designing both PU and PS to improve vehicle compatibility. Several automobile manufacturers are voluntarily re-designing their PU to make them more compatible with PS[4]. However, industry wide design improvements of both PU and PS will be needed to reduce the effect of mismatch.

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