M. Shimamura, K. Okamura
Institute for Traffic Accident Research and Data Analysis, Tokyo, Japan

H. Ohashi, M. Yamazaki
Tukuba Traffic Accident Investigation Office, Institute for Traffic Accident Research and Data Analysis, Japan

In-Depth Study of Front Seat Occupants in Accidents in Relation to Seat-Belt Use of Rear Seat Passengers

Abstract

Sedan type vehicles in which adult rear seat passengers were present and which were involved in frontal collisions were investigated, and the influence of unbelted rear seat passengers on the injuries of front seat occupants was studied. Unbelted rear seat passengers move forward during impact. It was observed that there were not only cases in which front seat occupants sustained injuries caused by direct contact with rear seat passengers, but also cases where front seat occupants received severe injuries due to additional force from rear seat passengers, either impacting directly or indirectly as a result of deformation of the front seat. Severe injuries of front seat occupants were observed in the latter cases. This research validates the importance of seat-belt use for rear seat passengers, not only to protect themselves but also to mitigate injuries of front seat occupants.

Introduction

Seat-belt use of front seat occupants is increasing yearly, and has reached over 90% for drivers and around 85% for front seat passengers. Recently, the reduction of fatalities in traffic accidents has been remarkable. One of the reasons for this is thought to be the increase in seat-belt use. On the other hand, seat-belt use of rear seat passengers has not increased and the ratio is no more than 20% [1].

The fatality rate of rear seat passengers in accidents is lower than that of front seat occupants, both drivers and front seat passengers, though fatalities of rear seat passengers are almost half that of front seat passengers and account for approximately 7% of total fatalities in four-wheel vehicles [1]. Occupants in vehicles that are involved in frontal collisions are impelled towards the front of the vehicle, and in the event of such a hazard, indications are that unbelted rear seat occupants tend to collide with the front seat or traverse the front seat, as a result of which they receive severe injuries due to collision with the instrument panel or windshield glass, and in some cases sustain fatal injuries due to ejection from the vehicle. Consequently, some research has been done on the effectiveness of seat-belts for rear seat passengers [2-5]. Results show that rear seat-belt use is effective in reducing passenger injuries, and that wearing seat-belts should therefore be imperative for rear seat passengers, too.

Some countries have made rear seat-belt use mandatory. Australia became the first country to enact legislation for rear seat-belt use, in Victoria in 1971 [6], followed by Germany in 1984, Canada in 1986, the UK in 1991 and Singapore in 2002. In fact, an increasing number of countries are demanding all occupants to wear seat-belts. However, mandatory seat-belt use for rear seats has been difficult to instigate in Japan. Reasons for this are the low rear seat occupancy rate and low fatality rate for rear seat passengers.

Indications are that unbelted rear seat passengers sometimes cause worse injury for front seat occupants [7]. On analyzing, from Japan's statistical accident data, head-on and rear-end collisions of sedan cars in which all passengers were injured, it was found that the number of fatally or seriously injured front seat occupants could be reduced by around 25-28% if unbelted rear seat passengers became accustomed to wearing seat-belts [1]. Such results indicate the importance of rear seat-belt use also in reducing injuries to front seat occupants.

However, the analysis of statistical accident data did not reveal the kind of injuries sustained by front seat occupants or how the movements of rear seat passengers affected the injuries of front seat occupants. Impact tests were carried out with anthropometric dummies, though the trajectory of a dummy might be different from that of a human being because of lower degree of freedom of movement of the dummy.

The aim of this research is to ascertain the injuries of front seat occupants based on in-depth accident data and also to investigate the influence of the movements of unbelted rear seat passengers on those injuries. Although a variety of accident and vehicle data was available, they were not necessarily sufficient for the purpose of this analysis. It is difficult to analyze injury mechanisms statistically. However, since it is considered possible to compare the postulated relationships between injury patterns and occupant movements with the in-depth accident data, the frequency and the severity of injuries relating to rear seat passengers were studied.

Method and Data

Postulated Movements of Rear Seat Passengers and Injury Mechanisms of Front Seat Occupants

Unbelted rear seat passengers move forward in a vehicle in a frontal collision. Generally, since there are front seats in front of rear seat passengers, these are the first vehicle parts with which the rear seat passenger collides. The following are modes of movement of a rear seat passenger depending on the impact severity and passenger seating position.

- Mode I: Rear seat passenger impacts a front seat and stops moving (including cases where a front seat deforms).
- Mode II: Rear seat passenger travels forward over the front seat (including cases where a front seat deforms).
- Mode III: Rear seat passenger passes between the driver's seat and passenger's seat resulting in torsional deformation of the front seats (this mode is typical for a center seat passenger).

Modes of movement were determined from the following information in investigated data and photographs: the imprinted marks on front seats, instrument panel and windshield glass, and deformation of front seats.

Front seat occupants and rear seat passengers move forward independently when a vehicle receives a frontal impact. After the forward movement of front seat occupants is stopped by force of restraint, they can be moved further due to the influence of rear seat passenger movement behind them. When front seat occupants receive additional injuries related to rear seat passenger movement, those injuries are characterized by the following patterns:

- Pattern A: Injuries appearing at the contact area due to direct collision of rear seat passengers with front seat occupants.
- Pattern B: Injuries caused by collision with vehicle parts as a result of forward movement accelerated either by direct contact with forward-moving rear seat passenger or force from front seatback impacted by rear seat passenger.
- Pattern C: Injuries caused mainly by pressure from front and back.

In the accident investigations, the injury source of pattern A is usually recorded as other occupants. Sources of injury similar to pattern B or C are recorded as vehicle parts that were impacted directly, and no information is reported if rear seat passengers had an influence. Therefore, in this research, injuries were classified as patterns A – C by considering movements of both front seat occupants and rear seat passengers. For instance, in the case of direct contact of rear seat passengers with front seat occupants, the injuries are categorized as pattern A if injuries are seen at the point of direct contact, but if injuries are observed in other areas, those injuries are categorized as pattern B or C. Next, in the case of belted front seat occupants who are pushed forward by seatbacks, such injuries can be categorized as pattern C if they are observed along the seat belt path, and if injuries are observed in other areas those injuries can be categorized as pattern B.

In-Depth Accident Data

ITARDA (Institute for Traffic Accident Research and Data Analysis) was established in 1992 for the purpose of investigating data and analyzing traffic accidents comprehensively and scientifically. ITARDA established an accident investigation office in the suburbs of Tokyo, and is continuously collecting accident data from approximately 300 cases per year. Over 2700 accidents were filed up to the end of 2002. At accident sites, the following items relating to vehicles are recorded: specifications of vehicles and equipment, damage status, deformation areas and volume, and other essential information. Vehicle movements are analyzed based on the recorded information, vehicle deformation is classified as CDC code according to SAE J224, and impact severity is evaluated as BEV (Barrier Equivalent Velocity) or delta-V. Seat-belt use is determined by compiling the following information: imprints on seat-belt devices, vehicle impact severity, vehicle parts impacted by occupants and injury of occupants. Injury of an occupant is classified by AIS 90 code based on the medical diagnosis by physicians, and injury sources are determined by compiling the following information: deformation or impact marks remaining on vehicle parts, location of injury and injury patterns on occupants as well as occupant kinematics.

In this research, vehicles analyzed were the sedan type with rear seats that were involved in frontal collisions recorded in 1993–2002 accident files. Frontal collision was determined by the horizontal impact zone of CDC code F, and impact angle was 10–02 o'clock. Station wagons or commercial vehicles were included in the analysis if they were derived from sedan passenger cars. But vehicles with major deformations, vehicles involved in multiple collisions and vehicles that hit vulnerable road users were excluded.

Vehicles with rear seat passengers were 142 in total, and vehicles in which at least one adult rear seat passenger aged 16 years or older was present were 104. The number of adult rear seat passengers was 141. Of the 141 rear seat passengers, 52 were seated on the right, in the back of the driver's seat*, 78 on the left, in the back of the front passenger's seat, and 11 in the middle. There were 8 belted passengers, 123 unbelted and 10 unknown. Since a child weighs much less than an adult, the influence on front seat passengers is considered so small that this research analyzed only the movement of unbelted adult rear seat passengers.

Results

Moving Area of Rear Seat Passengers

The correlation between seating locations and moving area of rear seat passengers is shown in table 1. There are 29 cases with no evidence of contact with the vehicle at all. It was found that 19 rear seat passengers moved forward beyond the front seats: 7 hit the windshield glass, 7 the instrument panel, and 5 the seating zone of front seat occupants. 5 out of the 19 rear seat occupants were seated in the middle.

Moving area \ Rear seat	Left side		Middle		Right side		Total
	Fore	Diag-onal	Fore	Diag-onal	Fore	Diag-onal	
Windshield	3	1	0	2	0	1	7
Instrument p.	1	2	0	3	1	0	7
Seating zone	2	2	0	0	1	0	5
Front seat	41	7	0	6	34	5	93
No contact	19		0		10		29
Total	78		11		52		141

(“Fore” indicates the number of cases in which a rear seat passenger impacted the seat in front, and “Diagonal” indicates the number of cases in which a rear seat passenger made contact with both front seats. Seating zone means seating area in front of the seatback of a front seat.)

Tab. 1: Seating locations and moving areas

Next, the direction of movement of rear seat passengers was analyzed. There were 6 cases in which the right rear seat passenger contacted the left front seat diagonally, and 12 cases where the left rear seat passengers impacted the right front seat. Among 14 rear seat passengers who moved forward beyond the front seats and who were not seated in the middle, 6 moved forward and made contact with the front seat diagonally opposite to them.

Because none of the rear seat passengers moved forward beyond the front seats among passengers who wore seat-belts or whose seat-belt use was unknown, 123 of unbelted rear seat passengers were analyzed in the following sections.

Movements of Unbelted Rear Seat Passengers and the Injuries of Front Seat Passengers

Movement modes of rear seat passengers are shown in table 2. Excluding 22 cases in which no imprints from contact were observed, mode II and mode III accounted for 6 and 13 cases respectively. The remaining 82 cases were accounted for by mode I, and 18 out of the 82 mode I cases impacted the front seat diagonally opposite to them.

Next, the cases where injuries of front seat occupants appeared to be influenced by rear seat passengers were extracted by excluding the following cases: cases where no corresponding front seat occupants were present, cases where front seat occupants received no injury, and cases in which it was considered to be absolutely no rear seat passenger influence even though injury was

* It should be noted that vehicles run on the left side of the road in Japan, and that the driver is seated on the right of the vehicle and the front passenger on the left.

	Rear seats			Total
	Left	Middle	Right	
No contact observed	15	0	7	22
Mode I — Fore	35	0	29	6
Mode I — Diagonal	7	6	5	18
Mode II	6	0	0	6
Mode III	5	5	3 (Note 1)	13
Total	68	11	44	123

(Note 1: There were 2 cases in which rear seat passengers made contact with the seat in front and slid after collision.)

Tab. 2: Movement modes of unbelted rear seat passengers

sustained. Table 3 contains a detailed list of 11 typical cases, in which mode I cases appear the most frequently. Two cases of model I are introduced here as examples.

Firstly, in case No. 2 in table 3, which is classified as mode I, the vehicle's BEV (Barrier Equivalent Velocity) measure of impact severity was approximately 45km/h. The unbelted passenger seated in the left rear seat contacted a front seat, and caused a large deformation of the front seat whose seatback bent forward, though no forward movement beyond the front seat was observed (see figure 1). The belted passenger who was sitting in the left front seat sustained a frail chest with lung contusions (AIS 4). There was a possibility that the severe rib fractures were related to the additional force of the rear seat passenger acting through the seatback.

In case No. 4 in table 3, the vehicle sustained an impact severity, BEV, of approximately 30km/h. The unbelted passenger was seated in the left rear seat, and collided with the left front seat and also the right front seat (see figure 2). No evidence was observed of forward movement beyond the front seats.

The belted left front passenger whose airbag was deployed in the collision sustained small-bowel laceration (AIS 3). It was assumed that this injury was related to the fact that the abdomen of the belted front seat passenger was pressed between the lap belt and seatback. The lap belt's effect on the abdomen could have been influenced by the contact of the rear seat passenger with the right edge of a seatback, causing displacement of lap belt linked to the inner belt.

Fig. 1: Deformation of front seat (No. 2)

Fig. 2: Deformation of front seats (No. 4)

Injury Patterns of Front Seat Occupants

In addition to 11 cases shown in table 3, other cases in which injuries of front seat passengers seemed to be related to rear seat passengers were listed, based on movement relations. A total of 22 cases were listed and injury patterns of these cases are shown in table 4.

Injury patterns of front seat occupants appear to have the following characteristics:

Pattern A: A total of 2 injuries, abrasions of upper extremities and contusions over the whole body. Both injuries were AIS 1.

Pattern B: A total of 7 injuries with injuries mainly to the head, chest, pelvis, and upper extremities. There were 2 belted front seat occupants, and one

No	Front seat occupant involved						Rear seat passenger			vehicle	
	Seat	Gender Age	Seat belt Airbag	Major injury induced	Other injuries	Injury Pattern	Seated location	Movement Mode	Contact area	CDC Code	BEV (km/h)
1	Driver	M 20	Belted Deployed	Small bowel laceration (4)		C	RH	I	Edge	12FZEW5	65
2	Pass.	M 61	Belted Deployed	Frail chest (4)	Chest contusion (1), Abdomen contusion (1), Leg contusion (1)	C	LH	I	Center	12FZEW3	45
3	Pass.	F 71	Belted Without	Lumber spine sprain (1)	Chest contusion (1)	C	LH	I	Center	12FYEW3	40
4	Pass.	F 45	Belted Deployed	Small bowel laceration (3)		C	LH	I	Edge	12FDEW2	30
5	Pass.	M 21	Non Without	Pelvis fracture (3)	Face laceration (1)	C	LH	II	Center	12FREW5	60
6	Pass.	F 25	Non Without	Arm contusion (1)	Face laceration (2), Head contusion (1), Face penetratin (2), Leg contusion (1)	A	LH	III	Edge	01FDEW2	45
7	Pass.	M 20	Belted Deployed	Overall contusion (1)	Shoulder contusion (1), Abdomen contusion (1)	A	LH	III	Edge	12FZEW5	65
8	Driver	M 21	Non Deployed	Head laceration (1)		B	LH	III	Edge	12FYEW5	55
9	Driver	M 19	Non Without	Chest contusion (1)	Face laceration (1)	B	CTR	III	Edge	12FLEN3	45
10	Driver	M 44	Belted Without	Humerus fracture (2)	Tibia fracture (2), Pelvis fracture (2), Rib fracture (1), Face laceration (1), Arm laceration (1)	B	CTR	III	Edge	12FREW6	55
11	Driver	M 62	Belted Deployed	Small bowel laceration (3)	Cervical spine sprain (1), Chest contusion (1)	C	RH	III	Center	12FZEW3	45

The figure in parentheses for an injury means AIS. RH means right seat, the one behind a driver, LH is left seat which is behind the front passenger, CTR means middle seat. Edge means that rear seat passengers made contact with the edge of a front seat or the front seat diagonally opposite, whereas, center means that the rear seat passenger made contact around the center of front seat.

Tab. 3: Injuries of front seat occupants thought to be influenced by rear seat passengers

		Rear seat			Total
		Left	Middle	Right	
No front seat occupants		8	0	0	8
No imprints		15	0	7	22
Driver	Pattern A	0	0	0	0
	Pattern B	3	2	1	6
	Pattern C	0	0	6	6
	Unknown	2	(4)	29	35
Front seat passenger	Pattern A	1	1	0	2
	Pattern B	1	0	0	1
	Pattern C	7	0	0	7
	Unknown	31	(4)	1	36
Total		68	11	44	123

Tab. 4: Seating locations and injury patterns of front seat occupants

of them was assumed to have sustained a lumber spine sprain due to twisting of the upper body. Reported sources of these injuries were vehicle parts in front of the occupants, such as the A-pillars and instrument panel. Injury levels were AIS 1 or AIS 2, including 2 cases of bone fractures of the upper extremities. Regarding rear seat passenger movement, 2 cases were mode I, and the remainder mode III. There were cases of the front seat occupant seated on the opposite side as well as those with the occupant in the seat in front of the rear seat passenger.

Pattern C: A total of 13 injuries. In case of belted front seat occupants, injured body areas were the chest or abdomen, and the source of all injuries was reported to be the seat-belt. In the case of unbelted front seat occupants, femur bone fractures or pelvic fractures were listed, and these injuries were reported as indirect injuries due to the contact of legs with instrument panels. AIS 4 injuries were observed as internal organ injuries in case of belted front seat occupants. The movements of rear seat passengers have all modes, I through III. However, the front seat occupant seated in front of the rear seat passenger appeared to be most susceptible to the influence of the rear seat passenger.

Front seat / Rear seat passenger	Level of deformation			Total
	a	b	c	
Mode I	37	35	10	82
Mode II	0	2	4	6
Mode III	0	6	7	13
Total	37	43	21	101

Tab. 5: Movement modes of unbelted rear seat passengers and deformation of front seats

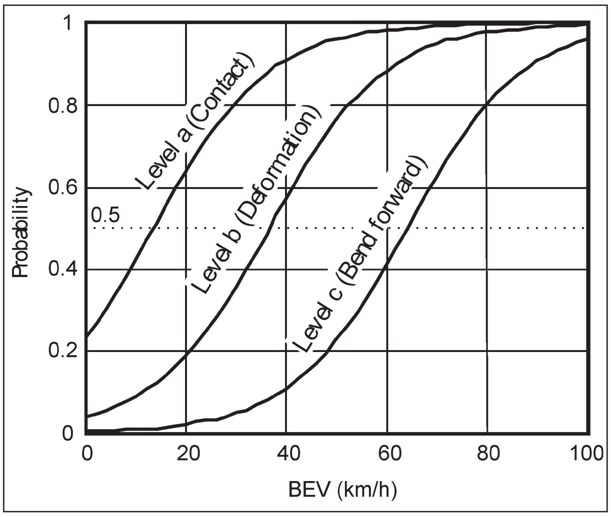

Fig. 3: Cumulative probability curve of seat deformation level

Front Seat Deformation

It is assumed that the larger the deformation of a front seat, the greater the influence on the front seat occupant's injury. Therefore, front seat deformation was analyzed by categorizing deformation in the following levels based on information from inquiry data and photographs: level a) some evidence of contact with rear seat passenger; level b) deformation at hinges or seat slide devices, or forward bending deformation of seatback; level c) seat back deformed beyond plumb line. Table 5 shows the relations between movement modes and deformation of front seats. In mode II or III, deformation was observed in all front seats. In the case of mode I, there were 10 cases of level c deformation and 35 cases of level b.

Front seat deformation is influenced by many factors, including the weight and physique of the rear seat passenger, the seat type, impact severity and vehicle deformation. In this research, the most influential factor, BEV, a measure of impact severity, was taken into account in gauging the level of deformation using the ordered response model [8-10]. The cumulative probability curve of deformation levels are shown against BEV in figure 3. With a cumulative probability of 0.5 as the threshold velocity of each deformation, it was found that level b for front seat deformation starts around 35km/h, and major deformation of the front seat, level c, begins around 65km/h.

Discussion

The analysis of the statistical accident data reveals that the injury level of front seat occupants in a vehicle in which none of the rear seat passengers wear seat-belts would be more severe than in vehicles in which all rear seat passengers wore seat-belts [1, 7]. In our research, injuries of front seat occupants were analyzed in consideration of how and in what kind of situations injury occurred by use of the detailed accident data. In the detailed accident data, vehicle parts were usually recorded if occupants contacted them, but records of contact between front and rear seat occupants are unfortunately rare. Furthermore, no information was recorded at all on whether injuries of front seat occupants were influenced by rear seat passengers. Therefore, this research focused on front seat occupants in cases where the movement or injuries of front seat occupants appeared to be influenced by rear seat passengers, either due to direct or indirect contact, and the injuries of front seat occupants were evaluated anew from the viewpoint of postulated injury mechanisms. There were some injuries included in patterns A, B and C even if those injuries could have occurred without a rear seat passenger. On the other hand, any injuries for which relations were difficult to explain were categorized as unknown. The seating location of rear seat passengers primarily depended on the testimony of witnesses, though in some cases the deformation of vehicle parts did not correspond with the claimed sitting position. Some of these were considered due to the unusual sitting posture of passengers, and there may have been cases where witnesses did not remember the sitting position of rear seat passengers. In this research, the latter data was eliminated. There was a total of 22 cases where the injuries of front seat passengers appeared to be influenced by the movement of rear seat passengers. Injuries of front seat occupants were categorized in patterns A to C, with 2 cases of pattern A, 7 cases of pattern B and 13 cases of pattern C.

There were many cases and severe injuries in pattern C. Injuries were markedly different depending on the seat-belt use of front seat occupants, and many serious injuries were observed in the chest or abdomen of belted occupants because of internal organ injuries. The chest skeleton usually bears the strong restraining force produced by the seat-belt or the airbag. If additional forces were applied from the back, chest injuries were critical. Abdominal injury is also caused by pressure from the seat-belt and the seatback, although the mechanism is slightly different. This injury is caused by the lap belt moving from iliac crests to abdomen, a phenomenon thought to be induced by seat deformation or direct impact of rear seat passenger on the lap belt.

As chest or abdominal injuries of pattern C were considered significant, a statistical study was conducted to ascertain the influence of unbelted rear seat passengers on the injury level to the chest and abdomen. Vehicles without rear seat passengers were chosen for comparison of vehicles where unbelted rear seat passengers were present instead of vehicles where belted rear seat passengers were present, since the latter number was so small. The injury level to chest and abdomen was divided into 5 ranks in order to apply the ordered response model [8-10]. Each rank was determined as follows: ranks 0 to 3 are the same as AIS 0 to 3 levels, and rank 4 includes AIS 4 to 6. As a result of the analysis, the probability of each rank regarding belted drivers aged 55 years or older was compared between vehicles with unbelted rear seat passengers and the vehicle without rear seat passengers (see figure 4.) The BEV of vehicles with rear seat passengers was found to be 4km/h lower than vehicles without rear seat passengers with a 50% probability and it is presumed that the injury level of front seat occupants would be severer at the same BEV.

Countermeasures to the movement of rear seat passengers or the deformation of front seats include installing a barrier or strengthening seat structures to halt forward movement of rear seat passengers. However, unbelted rear seat passengers have a range of movements during collisions, and it is difficult to use one countermeasure to cover all situations. From this point of view, seat-belt use of rear seat passengers is very effective in protecting front seat occupants.

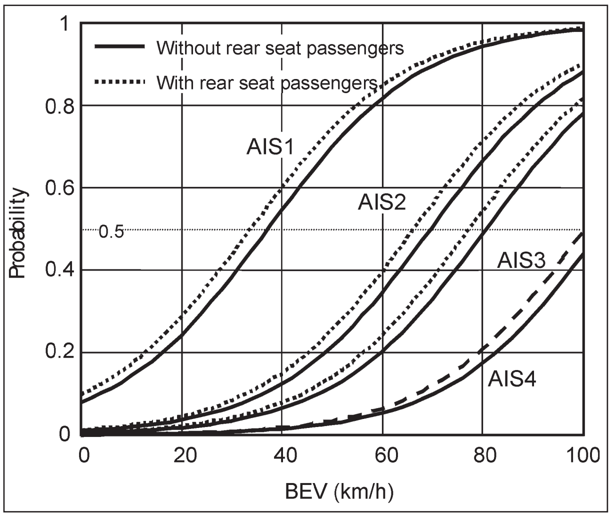

Fig. 4: Cumulative curve of probabilities of injury level of front seat occupants with and without unbelted rear seat passengers
References: Male drivers aged 55 years or older, belted, in ordinary sedan cars without airbag

As results of statistical accident data and detailed accident data, it was revealed that seat-belt use for rear seat passengers is effective not only in mitigating injuries to themselves but also important in reducing injuries to front seat occupants. Nevertheless, there is no indication of an increase in seat-belt use of rear seat passengers as a consequence. The best way to increase belt use is perhaps regulation and enforcement. The seat-belt use of rear seat passengers reached around 80-85% in Victoria, Australia, which introduced mandatory seat-belt use also for rear seats in 1971. In Canada, which also made use of rear seat-belts compulsory, seat-belt use for rear passengers reached 80% [11]. However, in both countries, the rate of seat-belt use in rear seat is still lower than that of front seats. Just before enforcing the regulation, it would be necessary to ask vehicle users to cooperate. Public relations and other enlightenment measures by government are also important. Such enlightenment work aims to increase seat-belt use by appealing not only to the sense of self-protection from one's own seat-belt but also by raising awareness of how injuries to front passengers could be reduced if rear passengers also wore seat-belts. Furthermore, not only should there be appropriate information available to the public and campaigns mounted, but continuous activities also are necessary to stimulate public awareness.

Injuries are influenced by many factors, including age, gender and occupant physique, impact severity, impact direction, vehicle deformation and the kind of restraint system. Therefore, it would be necessary to investigate detailed accident data continually, and to analyze the relations between rear seat passengers and front seat occupants statistically considering the various factors involved.

Summary

In frontal collisions, most unbelted rear seat passengers stop moving forward at the front seats, though other movements have been observed such as the case where a rear seat passengers flies over a front seat, and the case where a rear seat passenger moves forward beyond the front seats by passing between them.

There are several injury patterns of front seat occupants, one of the most frequent and severest injuries to the chest and abdomen being caused by pressure between the seat-belts or airbag from front and a seatback when pushed from behind by a forward-moving rear seat passenger.

Reducing casualties is important not only from the viewpoint of casualties of unbelted rear seat passengers but also as regards front seat occupants, whose injuries are influenced by unbelted rear seat passengers. Continuous publicity is required to keep the public informed of the necessity of using seat-belts even in the rear seats.

References

1 ITARDA: Investigation and research report on the seat belt effectiveness (in Japanese), 211p, 2003

2 EVANS, L., 1988:. Rear seat restraint system effectiveness in preventing fatalities, Accident Analysis and Prevention, 20 (2), 129-136

3 M. KRAFFT, C. NYGREN, C. TINGVALLET: Rear seat occupant protection. A study of children and adults in the rear seat of cars in relation to restraint use and car characteristics, Journal of Traffic Medicine, 18 (2), 51-60, 1990

4 J. PADMANABAN, R. M. RAY: Safety performance of rear seat occupant restraint systems, 36th STAPP 922524, 193-201, 1992

5 D. F. HUELKE, P. COMPTON: Rear seat occupants in frontal crashes – adults and children – the effects of restraint systems, IRCOBI, 1995

6 K. SMITH: Road safety: past, present and future, The Travel Bug conference, the Australian Institute of Traffic Planning and Management, 2000

7 M. SHIMAMURA, M. YAMAZAKI, G. FUJITA: Effect of Seat-belt Usage of Rear Seat Occupants on Injury Severity of Front Seat Occupants (in Japanese), Transaction of Society of Automotive Engineers of Japan 20024195, Vol.3 3, No. 2, 107-112, 2002

8 C. J. O'DONNELL, D. H. CONNOR: Predicting the severity of motor vehicle accident injuries using models of ordered multiple choice, Accid. Anal. and Prev., Vol.28, No.6, pp. 739-753, 1996

9 K. NAWATA, K. PROBIT, LOGIT, TOBIT. MAKI, A. et al.: Applied econometrics II (in Japanese), Section 4, pp. 237-270, Taga-Shuppan, 1997

10 M. SHIMAMURA, H. OHASHI, M. YAMAZAKI: The Effects of Occupant Age on Patterns of Rib Fractures to Belt-Restrained Drivers and Front Passengers in Frontal Crashes in Japan, Stapp Car Crash Journal, Vol. 47, pp. 349-365, 2003

11 Transport Canada: Results of Transport Canada's July 2001 Survey of Seat-Belt Use in Canada, October 2001, Fact Sheet #RS 2001-07, 2001