TRAFFIC ACCIDENT ANALYSIS TOWARDS THE DEVELOPMENT OF AN ADVANCED FRONTAL CRASH TEST DUMMY INDISPENSABLE FOR FURTHER IMPROVING VEHICLE OCCUPANT PROTECTION PERFORMANCE

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ABSTRACT

In this study, authors investigated and analyzed the injured body region and injury type for vehicle occupants from recent traffic accident statistics; that will be a basis to determine what human body regions should be evaluated in the frontal crash test, and what injury parameters should be measured utilizing an advanced test dummy. From the traffic accident statistics of the National Police Agency (NPA) in 2004 to 2008, the number of injured front seat occupants (i.e., drivers and passengers) by injury severity of vehicles damaged on front in the vehicle-to-vehicle accidents and the single vehicle accidents were collected. This then was analyzed by the seatbelt use, gender, and age group.

In five years from 2004 to 2008, the fatalities (the sum of drivers and passengers) due to the head and thorax injuries since 2005 tended to decrease conspicuously, whereas fatalities due to abdominal injuries were almost constant except for a slight increasing in 2008 from 2007. Reviewing the fatalities with regard to the seatbelt use, gender, and age group, more frequent injured body regions of the fatalities were the thorax, head, and abdomen. Of these, the most frequent injury types were organ injury on the thorax and abdomen, and skull fracture. Reviewing the fatalities by age group, the fatality rate was highest with injuries on the head in case of under 25 year olds, and was highest on the abdomen in cases of 26-64 year olds and over 65 year olds.

According to investigation and analysis in this study, in order to further improve the occupant protection performance during frontal crash, it was suggested that the abdominal injury that is impossible to evaluate in the Hybrid III and the injury measurement capability of the abdomen are particularly requested for a future frontal dummy.

INTRODUCTION

Understanding the real-world's vehicular accident situation is indispensable in the crash test dummy development process. The accident data analyzed statistically will be a basis to determine what human body region should be evaluated in the crash test, and what injury parameters should be measured utilizing a test dummy. Currently, though the Hybrid III frontal crash test dummy is used worldwide, a more advanced dummy with more biofidelity and higher measurement performance is requested for more sensitively evaluating the advanced restraint devices to further improve safety performance. Under these circumstances, an advanced frontal crash test dummy THOR (Test Device for Human Occupant Restraint) has been developed in the United States[1], and further development and evaluation of the THOR are in progress under the international efforts in order to further improve the biofidelity and measurement performance[2].

This paper reports the results of the investigation and analysis of the injured body region and injury type for occupants in front-damaged vehicles based on recent traffic accident statistics. It is also pointed out that towards the future discussion regarding what human body regions should be evaluated in the frontal crash test, and what injury parameters should be measured utilizing the dummy.

ACCIDENT DATA SOURCE

The traffic accident database used in this analysis is the traffic accident statistics the NPA collected from 2004 to 2008. The NPA traffic accident statistics covers all traffic accidents with one or more injured persons who occurred in Japan, and these statistics data are managed by ITARDA (Institute for Traffic Accident Research and Data Analysis). The injury severities of vehicle occupants in statistics are classified in four groups as follows:

a) fatalities (deaths within 24 hours from the accident),

b) serious injuries (injuries requiring medical treatment over 30 days from the accident),

c) slight injuries (injuries requiring medical treatment less than 30 days from the accident), and

d) no injuries (only drivers are collected).

The damaged areas of vehicles are classified in terms of eight directions as shown in Figure 1.

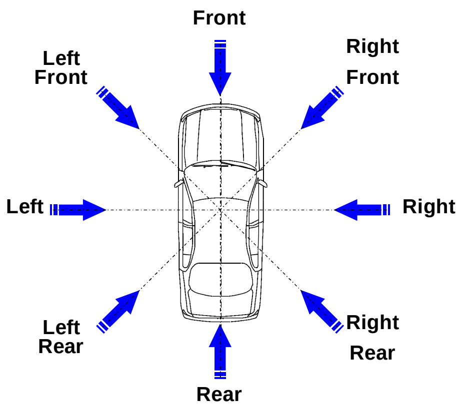

Figure 1. Classification of vehicle damage areas in NPA accident statistics

In this analysis, from the vehicle-to-vehicle accidents and the single vehicle accidents in the NPA traffic accident statistics from 2004 to 2008, vehicles damaged in the front, front right or front left of classifications shown in Figure 1 were defined as front-damaged vehicles. The number of these drivers and front passengers were collected by the classified injury severities. Both of vehicle-to-vehicle accidents and single vehicle accidents, the vehicle categories of the front-damaged vehicles were focused on the passenger cars and mini cars. As for the partner vehicles in the vehicle-to-vehicle accidents, not only the passenger cars and mini cars but also wagons and vans were subjects. As for the damaged areas of the partner vehicles, all the areas defined in Figure 1 were included. Accordingly the accident configurations of front-to-side crash and front-to-rear crash in addition to front-to-front crash were included. Regarding the single vehicle accidents, all opposing objects such as roadside structures, trees and parked vehicles were included.

GENERAL CHARACTERISTICS OF EXTRACTED ACCIDENT DATA

Table 1 shows the number of occupant casualties (i.e., the sum of fatalities, serious injuries, slight injuries) from front-damaged vehicles and the cumulative total number of occupant casualties from all vehicles covered by the NPA traffic accident statistics[3] from 2004 to 2008. The numbers of fatalities, serious injuries and slight injuries from front-damaged vehicles corresponded to 21.9 %, 19.3 % and 6.0 %, respectively, of the total number of occupant casualties from all vehicles from 2004 to 2008.

Table 1.
Casualties of vehicle occupants from 2004 to 2008

	Occupants in Frontal Crashed Vehicles	Occupants in All Crashed Vehicles
Fatalities	*2,566 (21.9%)*	*11,722*
Serious Injuries	*18,965 (19.3%)*	*98,348*
Slight Injuries	*194,851 (6.0%)*	*3,274,738*

Drivers and Front Passengers by Injury Severity

Figure 2 shows the ratios of drivers and front passengers of the total number of front-seat casualties in vehicle-to-vehicle accidents and single vehicle accidents by injury severity. Both of vehicle-to-vehicle accidents and single vehicle accidents, irrespective of injury severity, the drivers accounted for about 80 % of the front-seat occupant casualties. Comparing to the occupant casualties by injury severity between vehicle-to-vehicle accidents and single vehicle accidents, the casualties from single vehicle accidents outnumbered the casualties from vehicle-to-vehicle accidents by 7:3 (1,879 : 687 persons) for fatalities, 6:4 (10,864 : 8,101 persons) for serious injuries, and 3:7 (53,979 : 140,872 persons) for slight injuries. Thus, the ratio of casualties of single vehicle accidents was trend on a high as the injury severity increased.

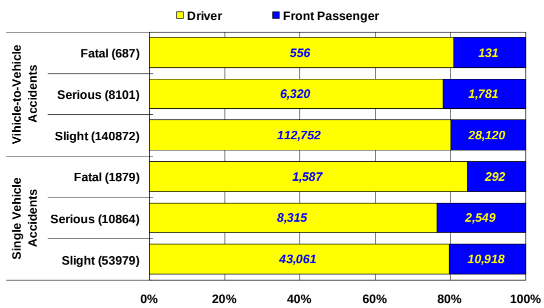

Figure 2. Ratio of drivers and front passengers by injury severity

Casualties by Seatbelt Use

Figure 3 shows the number of casualties by injury severity and the ratio by seatbelt use in the vehicle-to-vehicle accidents and the single vehicle accidents. Overall, the ratio of belted occupants in the vehicle-to-vehicle accidents was higher than that in the single vehicle accidents, for both drivers and front passengers. The ratio of belted occupants was trend on decrease as the injury severity increased, for both vehicle-to-vehicle accidents and single vehicle accidents. For fatalities, the belted drivers were about one-half of the vehicle-to-vehicle accidents and about one-third of the single vehicle accidents. However, the belted drivers accounted for over 80 % of serious injuries and slight injuries respectively, for both vehicle-to-vehicle accidents and single vehicle accidents.

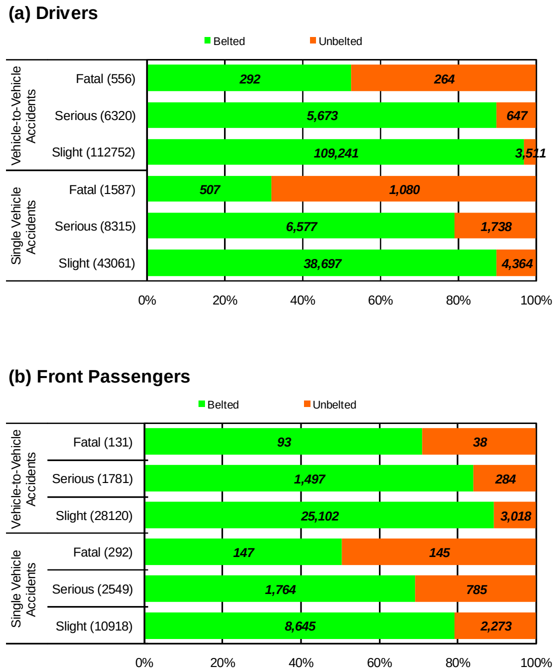

Figure 3. Ratio of casualties by seatbelt use and injury severity

Gender and Age Groups

Figures 4 and 5 show the distributions of casualties of the belted drivers and front passengers by injury severity, gender, and age groups in the vehicle-to-vehicle accidents and the single vehicle accidents. Age groups were classified in three groups of under 25 year olds, 26-64 year olds, and over 65 year olds. With regard to the belted drivers of both vehicle-to-vehicle accidents and single vehicle accidents, irrespective of injury severity, the number of 26-64 year old males was larger, however, the ratio of over 65 year old males increased as the injury severity. With regard to the belted front passengers of both vehicle-to-vehicle accidents and single vehicle accidents, the ratio of over 65 year old females increased as the injury severity.

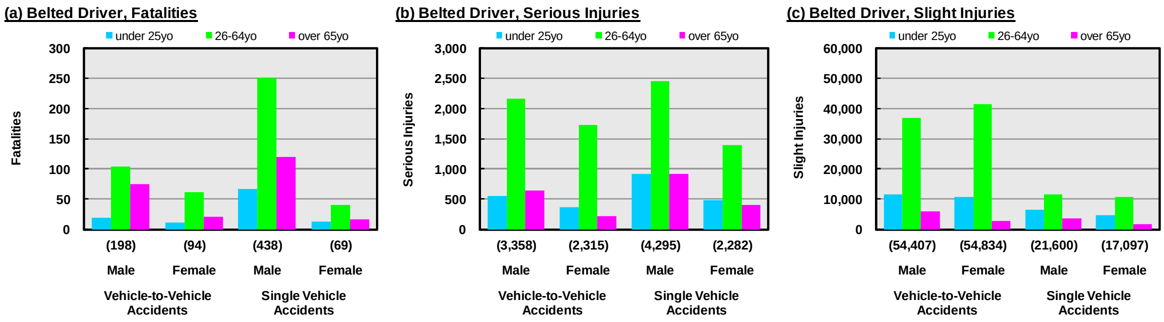

Figure 4. Belted driver casualties by gender and age groups

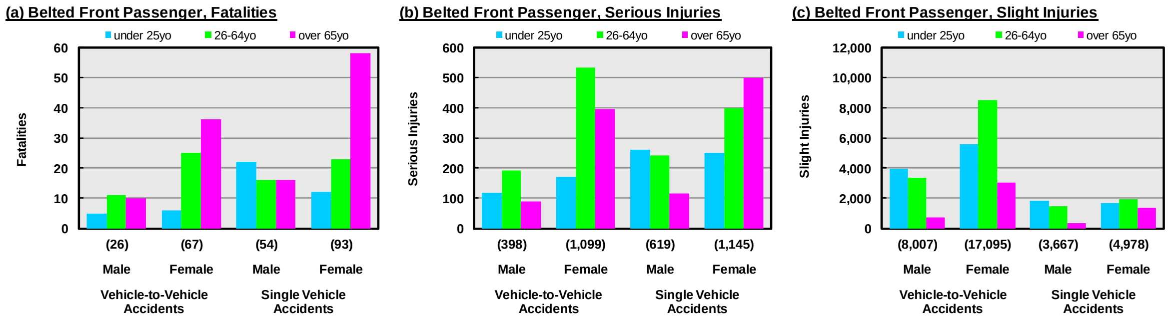

Figure 5. Belted front passenger casualties by gender and age groups

BELTED DRIVER'S INJURIES IN FRONTAL CRASH VEHICLES

In view of the above-mentioned finding that drivers account for about 80 % of front-seat casualties in front-damaged vehicles from both vehicle-to-vehicle accidents and single vehicle accidents, furthermore based on the purpose of this study, hereafter, the analysis was focused on the belted drivers. The fatalities, serious injuries, and slight injuries in the analysis were respectively the sum of vehicle-to-vehicle accidents and single vehicle accidents, and except analysis of five years trend, the cumulative total numbers in five years from 2004 to 2008 was used.

Five Years Trend by Injured Body Region

For the injured body region, the NPA traffic accident statistics generally records the most highest injured body region in traffic accidents. The statistics classify in eleven body regions: head, face, neck, thorax, abdomen, back, pelvis, arms, legs, overall body, and other. In this analysis, nine body regions excluding overall body and other were used as "injured body region" for analysis.

Figures 6 and 7 show the five years trend from 2004 to 2008 for the numbers of fatalities and serious injuries by the injured body region. For the fatalities, the head, thorax, and abdomen were frequent as the injured body region, throughout the period. The fatalities due to the head and thorax injuries since 2005 tended to decrease conspicuously, whereas the fatalities due to abdominal injuries were almost constant except for a slight increasing in 2008 from 2007. For the serious injuries, although the thorax and legs were frequent as the injured body regions most times, both trended to decline throughout the five year period, especially the legs were conspicuous.

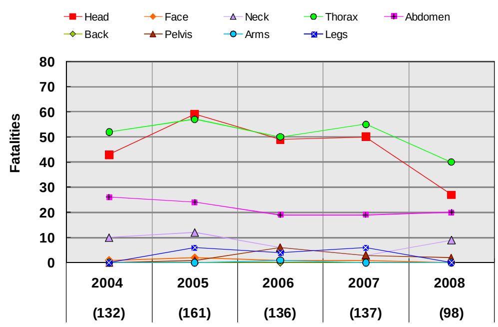

Figure 6. Five years trend of fatalities by injured body region (belted driver)

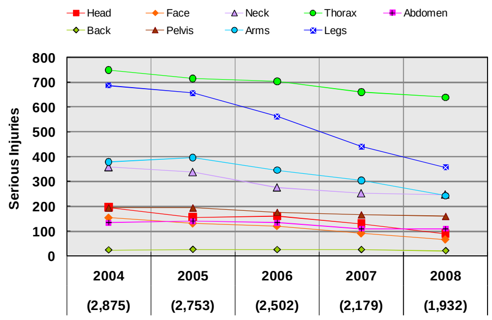

Figure 7. Five years trend of serious injuries by injured body region (belted driver)

Casualties and Injury Rates by Injured Body Region

Figures 8 to 10 show the numbers of belted driver fatalities, serious injuries, and slight injuries by injured body region, and fatality rate and serious+ injury rate by injured body region are shown in Figures 11 and 12. A fatality rate represents the number of fatalities divided by the total number of fatalities, serious injuries, and slight injuries, as in Equation (1). A serious+ injury rate represents the sum of fatalities and serious injuries divided by the total number of fatalities, serious injuries, and slight injuries, as in Equation (2).

$$Fatality\ Rate = \frac{Fatalities}{\sum(Fatalities, Serious\ Injuries, Slight\ Injuries)} \times 100(\%) \cdots (1).$$

$$Serious + Injury\ Rate = \frac{\sum(Fatalities, Serious\ Injuries)}{\sum(Fatalities, Serious\ Injuries, Slight\ Injuries)} \times 100(\%) \cdots (2).$$

As shown in Figures 8 to 10, for the fatalities, the thorax was most frequent as the injured body region, followed by the head and the abdomen. With regard to the serious injuries, the thorax was most frequent as the injured body region, however, there were fewer head injuries and more leg injuries, as compared to the fatalities. In the slight injuries, the neck injuries were most numerous among the injured body regions, and it accounted for about 60 % of slight injuries. Both fatality rates and serious+ injury rates shown in Figures 11 and 12 indicated the highest rate on the abdomen respectively; the fatality rate of abdomen was 2.2 times higher than the head, and the serious+ injury rate of abdomen was 1.9 and 1.4 times higher than the thorax and legs, respectively.

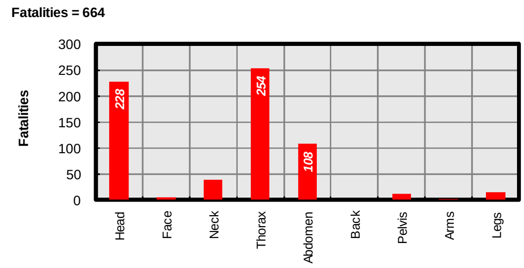

Figure 8. Fatalities by injured body region

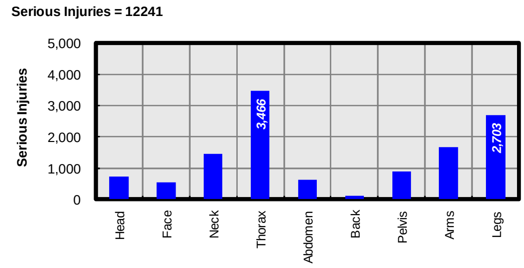

Figure 9. Serious injuries by injured body region

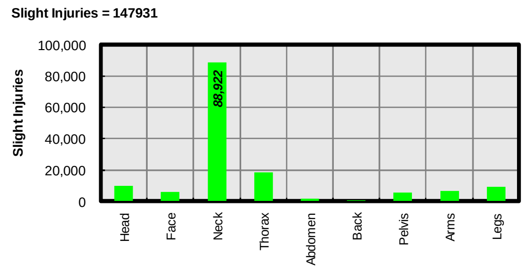

Figure 10. Slight injuries by injured body region

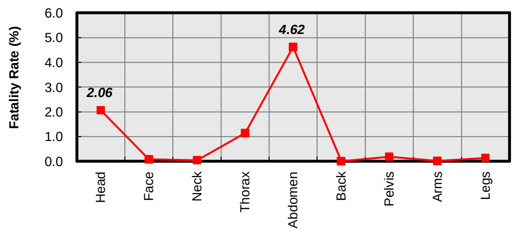

Figure 11. Fatality rate by injured body region

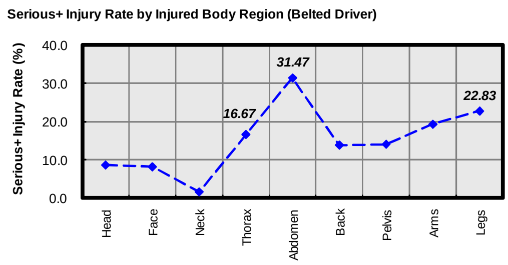

Figure 12. Serious+ injury rate by injured body region

Injury Circumstances by Estimated-delta V

The travel speed before a driver perceives a danger and takes avoidance procedure is recorded in the NPA traffic accident statistics, and this speed is named “travel speed just before the accident”. ITARDA calculates the amount of vehicle speed variation in crash by using this speed and vehicle kerb weight, and defines it as “Estimated-delta V”. The Estimated-delta V of a frontal crash vehicle in a vehicle-to-vehicle accident is calculated by Equation (3), (4) or (5) according to the damaged area of the partner vehicle (see Figure 1)[4]. In this study, calculated Estimated-delta V is classified in the following four groups, 0-20 km/h, 21-40 km/h, 41-60 km/h, and over 61 km/h, and the trend variation of injured drivers due to the change of Estimated-delta V was investigated. Estimated- delta V for single vehicle accidents is identical with the “travel speed just before the driver perceives a danger”.

- Collision partner’s damaged area ; Front, Right Front or Left Front

$$Estimated-delta\,V = M2/(M1+M2)\times(V1+V2)\cdots\cdots(3).$$

- Collision partner’s damaged area ; Rear, Right Rear or Left Rear

$$Estimated-delta\;V = M2/(M1+M2)\times(V1-V2)\cdots\cdots(4).$$

- Collision partner’s damaged area ; Right or Left

$$Estimated-delta\;V = M2/(M1+M2)\times V1\cdots\cdots\cdots\cdots(5).$$

Where,

M1 ; Mass of frontal crash vehicle

M2 ; Mass of collision partner

V1 ; Travel speed of frontal crash vehicle just before accident

V2 ; Travel speed of collision partner just before accident

Fatalities and injuries by Estimated-delta V

Figure 13 shows the numbers of fatalities, serious injuries and slight injuries by Estimated-delta V. The fatalities were frequent in 41-60 km/h and over 61 km/h, and these speed ranges accounted for about 80 % of fatalities. On the other hand, many serious injuries were distributed in 21-40 km/h and 41-60 km/h, and these speed ranges accounted for about 70 % of serious injuries. With regard to the slight injuries, the speed ranges of 0-20 km/h and 21-40 km/h accounted for about 80 % of slight injuries.

Injured body region by Estimated-delta V

Figures 14 to 16 show the distributions of injured body regions by Estimated-delta V for fatalities, serious injuries, and slight injuries. With regard to the injured body region on fatalities, the percentages of thorax, head, and abdomen were higher in all speed ranges, and the percentage of head increased as the delta V rose. For the serious injuries, the thorax accounted for about 20 % to 30 % in all speed ranges. Though the percentage of neck was higher in the low speed range, that percentage became lower while the percentage of the legs became higher as the delta V rose. For the slight injuries, the percentage of neck was the highest and accounted for 40 % to 70 % in all speed ranges.

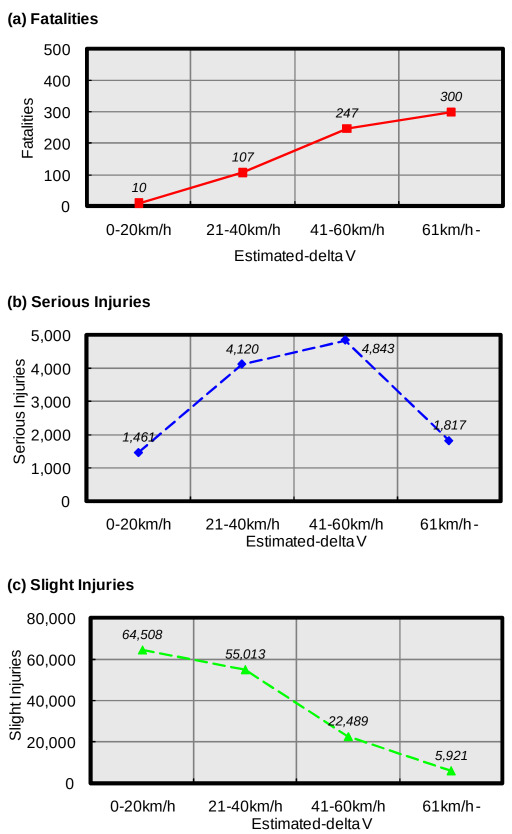

Figure 13. Fatalities and injuries by Estimated-delta V

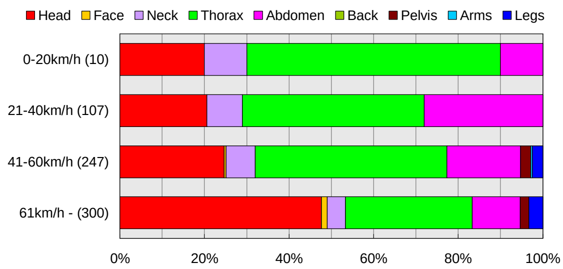

Figure 14. Distribution of injured body region of fatalities by Estimated-delta V

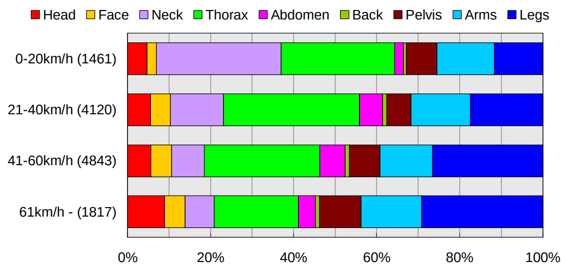

Figure 15. Distribution of injured body region of serious injuries by Estimated-delta V

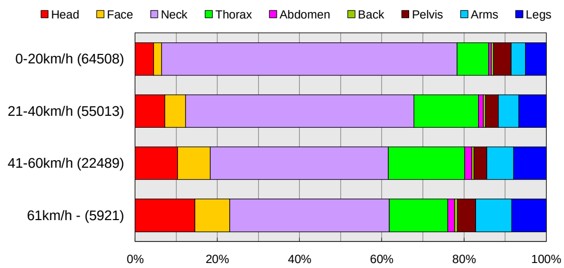

Figure 16. Distribution of injured body region of slight injuries by Estimated-delta V

Injured Body Region and Injury Type by Gender and Age Groups

In this section, the trend with regard to the injured body regions and injury types was investigated by gender and age groups. Of the injury types defined in the statistics, five types were applied in this study: fracture, organ injury, sprain, wound (including abrasion, laceration, contusion, etc.), and others. As in previous section, three age groups were applied: under 25 year olds, 26-64 year olds, and over 65 year olds.

Injured body region and injury type of male drivers Figures 17 and 18 show the injured body regions and injury types with regard to the fatalities and serious injuries of male drivers by age groups. Though the number of fatalities greatly differed among the three age groups, a fracture or a wound of head, and an organ injury of thorax or abdomen were frequent in under 25 year olds and 26-64 year olds. In over 65 year olds, a fracture, a wound or an organ injury of thorax, and an organ injury of abdomen were outnumbered than the head injuries. In the case of serious injuries, though a fracture was the leading injury type in all the age groups, the leg fracture were most frequent in under 25 year olds, and both thorax and leg fractures were equally frequent in 26-64 year olds. Contrary to this, the thoracic fracture was most frequent in over 65 year olds.

Injured body region and injury type of female drivers Figures 19 and 20 show the injured body regions and injury types with regard to the fatalities and serious injuries of female drivers by age groups. Though it is difficult to understand a trend because the fatalities of female drivers were fewer than male drivers, the fatalities of female drivers differed from male drivers in that an organ injury of thorax outnumbered a fracture and a wound of head in 26-64 year olds. Similar to male drivers, many serious injuries of female drivers were injured due to a fracture in all the three age groups. However, it differed from male drivers in that a fracture of thorax outnumbered a fracture of legs in 26-64 year olds.

Fatality rate by injured body region, gender and age groups Figure 21 shows the fatality rates of belted drivers by injured body regions, gender, and age groups. For both male and female drivers, the fatality rate of head was the highest in under 25 year olds, however, the fatality rate of abdomen was the highest in 26-64 year olds and over 65 year olds. In the case of male drivers, the fatality rates of abdomen in 26-64 year olds and over 65 year olds were respectively three times and six times higher than the fatality rate of head in under 25 year olds.

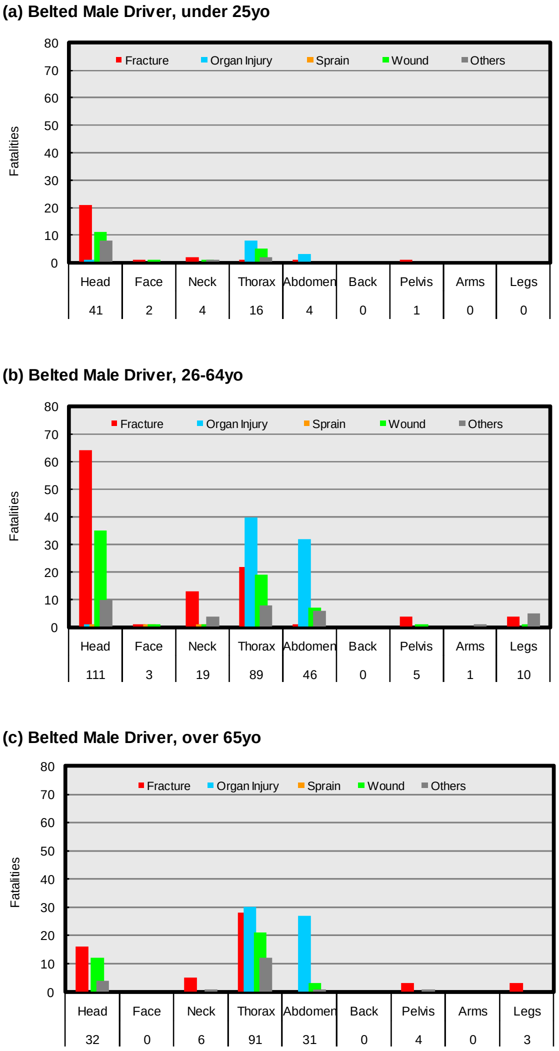

Figure 17. Injured body region and injury type by age groups for fatalities of male drivers

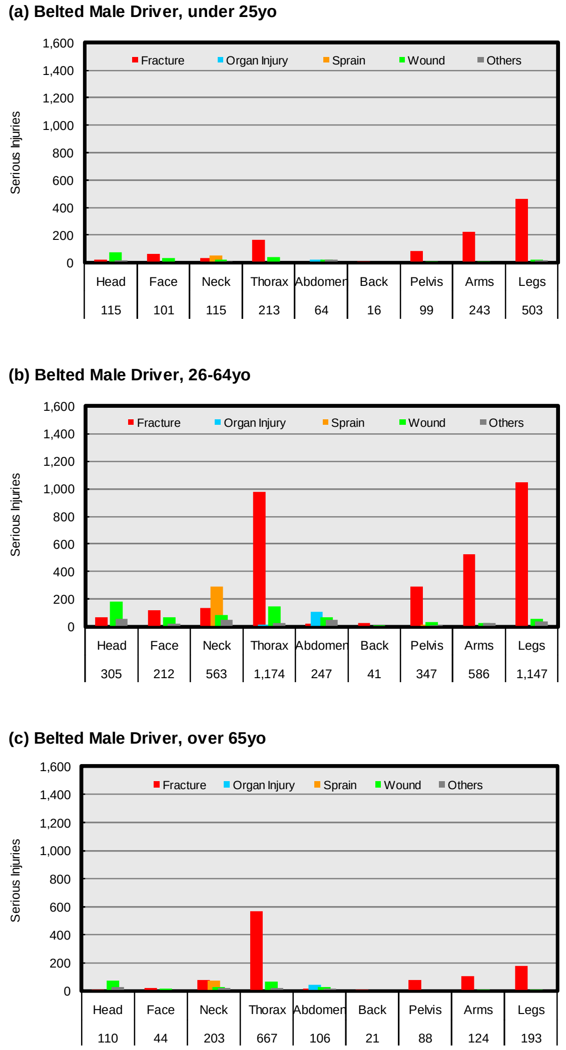

Figure 18. Injured body region and injury type by age groups for serious injuries of male drivers

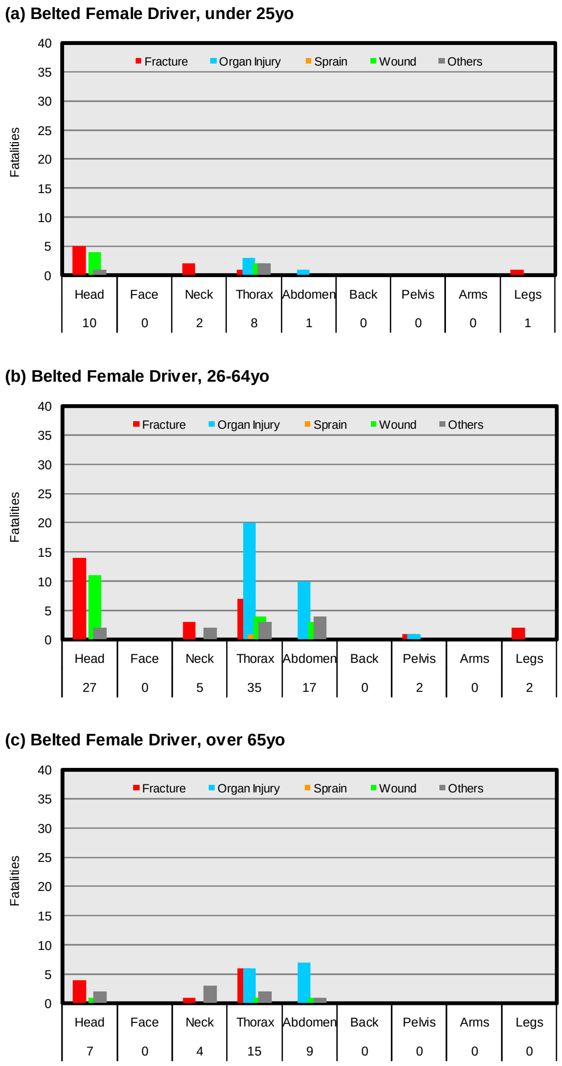

Figure 19. Injured body region and injury type by age groups for fatalities of female drivers

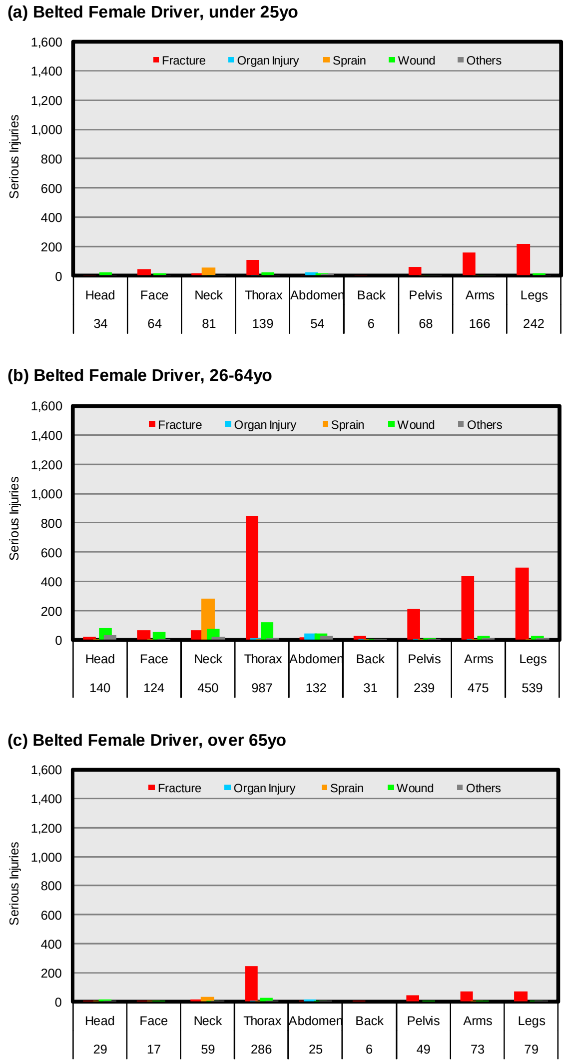

Figure 20. Injured body region and injury type by age groups for serious injuries of female drivers

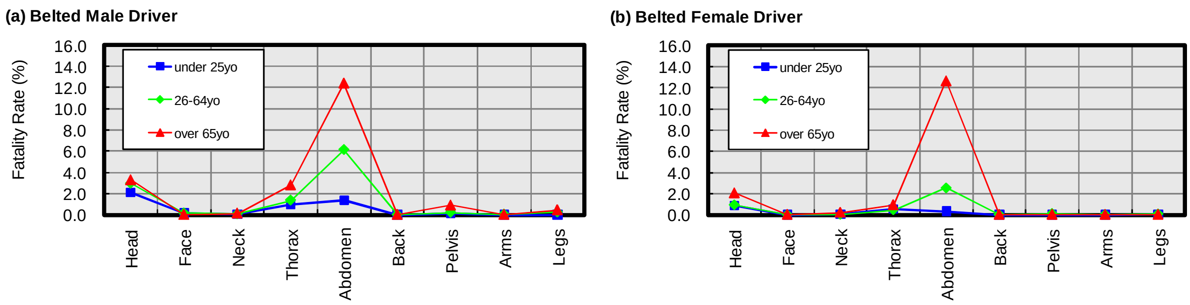

Figure 21. Fatality rate of belted drivers (male and female) by injured body region and age groups

Correlation of Injured Body Region and Injury Source

This section shows the results that analyzed the correlations between the injured body regions of belted drivers and the injury sources. It was not classified by gender and age groups.

Figures 22 and 23 show the correlations between injured body regions and injury sources for the cases of fatality caused by an organ injury and a fracture.

The fatalities caused by an organ injury had almost injury to the thorax or abdomen, and the injury source was the steering wheel in most of these cases. Many fracture fatalities had injury to the thorax and head. While the injury source to the thorax was the steering wheel in many cases, the injury source to head had steering wheel, windshield, other interior, etc.

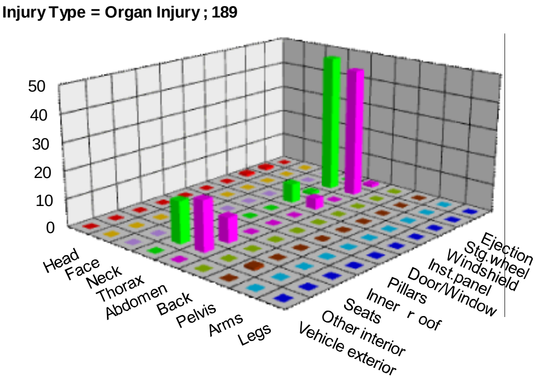

Figure 22. Correlation of injured body region and injury source of fatalities (Organ Injury)

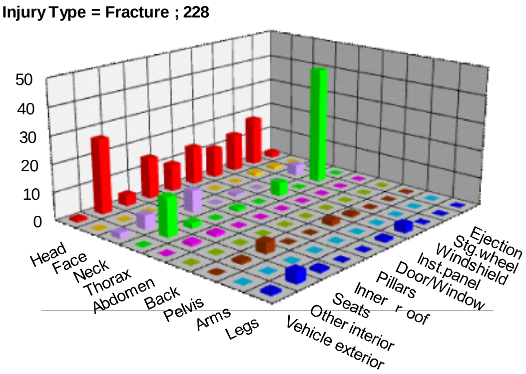

Figure 23. Correlation of injured body region and injury source of fatalities (Fracture)

Figure 24 shows the correlation of injured body regions and injury sources for serious injuries due to a fracture. The most frequent combination proved to be thorax and steering wheel, followed by the combination of legs and other interior.

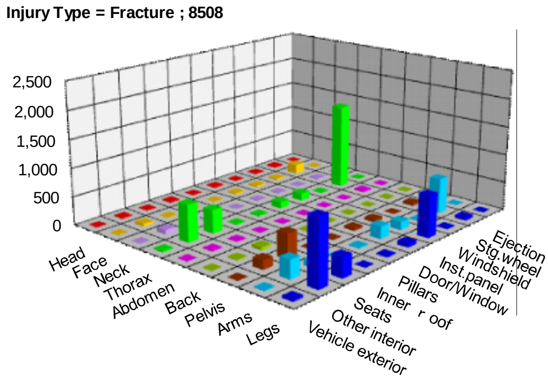

Figure 24. Correlation of injured body region and injury source of serious injuries (Fracture)

SUMMARY

Authors investigated and analyzed the injured body region and injury type for occupants in vehicles damaged on front from recent traffic accident statistics towards the future discussion regarding what human body regions should be evaluated in the frontal crash test, and what injury parameters should be measured utilizing the dummy. The findings were as follows:

General Output deduced by Accident Data Analysis

- The drivers accounted for about 80 % of front seat occupants for all of fatalities, serious injuries, and slight injuries.
- As the severity of injury rose, the ratio of seatbelt use decreased for both drivers and front passengers.
- Belted drivers accounted for one-half of fatalities in vehicle-to-vehicle accidents and about 30 % of fatalities in single vehicle accidents. However, the ratios of belted drivers exceed 80 % of both serious and slight injuries.

Belted Driver's Injuries in Frontal Crash Vehicles

- The number of fatalities caused by head or thorax injuries was on the decrease since 2005, but fatalities due to abdominal injury leveled off in the past five years. Regarding serious injuries, thorax and leg injuries were on the decrease since 2005, especially the legs were conspicuous.
- For the fatalities, the thorax, head and abdomen

were frequently injured body regions, and the thorax and leg injuries were more numerous among injured body regions in the serious injuries. For the slight injuries, neck injuries accounted for about 60 %. However, as for fatality rates and serious+ injury rates, the highest rates were respectively recorded by abdominal injuries.

- About 80 % of fatalities were distributed in Estimated-delta V of 41-60 km/h and over 61 km/h. Estimated-delta V of 21-40 km/h and 41-60 km/h accounted for about 70 % of serious injuries. 0-20 km/h and 21-40 km/h accounted for about 80 % of slight injuries.
- As Estimated-delta V rose to middle and high speed levels, the percentage of head injuries increased among fatalities, similarly, the percentage of leg injuries expanded among serious injuries.
- Male driver's fatalities were frequent for the fracture and wound of head in under 25 year olds and 26-64 year olds, furthermore, the organ injuries of thorax or abdomen were also frequent. However, in over 65 year olds, the fracture, wound and organ injury of thorax and the organ injury of abdomen outnumbered the fracture and wound of head.
- Male driver's serious injuries were most frequent for leg fracture in under 25 year olds. In 26-64 year olds, the fractures of thorax and legs were equally frequent. With regard to over 65 year olds, thoracic fracture was most frequent. Thus, the overall trend was that the percentage of thoracic fracture increased as male drivers grew older.
- Female driver's fatalities differed from male drivers in that the organ injury of thorax outnumbered the fracture and wound of head in 26-64 year olds.
- Female driver's serious injuries were similar to male drivers in that fracture was frequent in all the age groups, however, differed from male drivers in that the thoracic injury outnumbered the leg injury in 26-64 year olds and over 65 year olds.
- Regarding fatality rates by injured body region, a rate of head was the highest in under 25 year olds whereas a rate of abdomen was the highest in 26-64 year olds and over 65 year olds, for both male and female drivers.
- Fatalities due to organ injury were numerous in the thorax and abdomen as injured body region, and the injury source was almost the steering wheel.
- Fatalities caused by fracture were frequent in the thorax and head as injured body region. While the steering wheel proved to be the main injury source to thoracic fracture, the injury source to skull fracture had the steering wheel, windshield, and other interior, etc.
- With regard to serious injuries of thorax fracture caused by the steering wheel was most frequent, followed by the serious injuries of legs caused by other interior.

CONCLUSIONS

With respect to fatalities and serious injuries by injured body region, the casualties casued by the head, thorax, and leg injuries outnumbered the casualties due to abdominal injury. However, the abdominal injury was the highest for the fatality rates and the serious+ injury rates. In five years from 2004 to 2008, fatalities casued by head or thoracic injuries were trend on decrease, while fatalities due to abdominal injury leveled off. These results suggest that in order to further improve the occupant protection performance during frontal crash, the abdominal injury that is impossible to evaluate in the Hybrid III and the injury measurement capability of the abdomen are particularly requested for a future frontal dummy (see APPENDIX).

FUTURE WORK

This paper has reported the results of general analysis from traffic accident statistics regarding the injury situations that focused on the front seat occupants, especially the drivers, of frontal crash vehicles. It will be necessary to consider the influence of airbag (its activation or non-activation) on the injury severity towards the future discussion regarding what human body regions should be evaluated in the frontal crash test, and what injury parameters should be measured utilizing the dummy. Consequently, more studies will be needed to compare injury status between airbag deplyment and non-deplyment cases. Furthermore, because the detailed information of the human injury pattern was not included in the NPA accident statistics, it was impossible to investigate which specific organ was injured well as the mechanism involved. Therefore, it will be necessary to investigate and analyze the human injury mechanism in detail, based on the new establishment of the integration with the Medical Trauma Registry Database. These studies provide a basis for global discussion regarding the development (including harmonization of specifications) of the advanced frontal dummy by clarifying the vehicle accident situations in Japan which includes many relatively smaller cars than that in the United States and in Europe.

REFERENCES

[1] Shams T. et al.: Development of THOR-NT: Enhancement of THOR Alpha-the NHTSA Advanced Frontal Dummy, 19th ESV, 2005

[2] Yaguchi M. et al.: Comparison of Dynamic Responses of the THOR-NT and Hybird III in Offset Frontal Crash Test, 21st ESV, 2009

[3] National Police Agency: http:// http://www.npa.go.jp/koutsuu/index.htm

[4] Shimamura, M. et al.: Method to evaluate the effect of safety belt use by rear seat passengers on the injury severity of front seat occupants, Accident Analysis and Prevention Vol.37, issue1, p5-17, 2005

APPENDIX

Table A1. Comparison of the instrumentations of the THOR-NT and the Hybrid-III

	THOR-NT(Current Ver.)	Hybrid-III(Typical Configuration)
Head	**9 Uniaxial Accelerometers**	**Yes** (1 Triaxial Accelerometer at Head C.G.)
	1 Biaxial Tilt Sensor	No
Face	**Five Uniaxial Load Cells**	No
Neck	**Upper Neck Load Cell (6 channels)**	**Yes**
	Lower Neck Load Cell (6 channels)	**Yes**
	Front Neck Cable Load Cell	No
	Rear Neck Cable Load Cell	No
	Head Rotation Potentiometer	No
Thorax	**CRUX Deflection Units - 3 Dimensional Displacement at each of Four Locations (UL, UR, LL, LR)- 4 CRUX units @ 3 channels each;**	**Yes** (One-directional Displacement String Potentiometer)
	1 Triaxial Accelerometer at the C.G.	**Yes**
Mid Sternum	**1 Uniaxial Accelerometer**	No
Upper Abdomen	**Uni-directional Displacement String Potentiometer**	No
	Uniaxial Accelerometer	No
Lower Abdomen	**DGSP Deflection Units - 3 Dimensional Displacement at L & R Locations (2 DGSP units @ 3 channels each)**	No
Spine	**1 Triaxial Accelerometer at T1 location**	No
	1 Triaxial Accelerometer at T12 location	No
	T12 Load Cell (5 channels)	**Yes**
	4 Biaxial Tilt Sensors	No
Pelvis	**Acetabulum Load Cell (left and right, 3 channels each)**	No
	Iliac Crest Load Cells (left and right, 1 channel each)	No
	1 Triaxial Accelerometer at Pelvis C.G.	**Yes**
Femur	**Femur Load Cell (left and right, 6 channels each)**	**Yes**
Knee	**Knee Shear Displacement, L&R**	**Yes**
Lower Extremity	**Upper Tibia Load Cell (left and right, 4 channels each)**	**Yes**
	Lower Tibia Load Cell (left and right, 5 channels each)	**Yes**
	Tibia Acceleration (left and right, 2channels each)	No
	Achilles Tendon Load Cell (left and right, 1 channels each)	No
	Ankle Joint Rotation Potentiometers (left and right, 3channels each)	No
	Foot Acceleration (left and right, 3 channels each)	No