The Present Situation of Pedestrian Accidents in Japan

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ABSTRACT

In order to grasp the present situation of pedestrian accident in Japan, we have analyzed national statistical data on traffic accidents and conducted in-depth case studies on traffic accidents which involved 113 pedestrians against front portions of bonnet type cars. As a result, it is found that the age group of 60 years or older account for about half of the fatalities, and that passenger cars account for 60% or so of four-wheelers involved in those accidents. About 70% of pedestrians for passenger cars were hit by the front portions of the vehicles. Head injuries caused by impacts against top surface of bonnets and leg injuries caused by impacts against front bumpers show high incidence rates. 1) Children, in particular, account for two-thirds of impacts against top surface of bonnets, 2) injuries in chest, abdomen and pelvis tend to become severer for adults than for children, given the same impact speed, and 3) femur bone fractures of children are found when the bumper lead is of length about 80 mm or more. It will be hence vital to take sufficient account of the difference in stature when considering the protection of pedestrians in relation to vehicle structures, since contacted areas of vehicles differ between adults and children, even if the region of injuries is the same, and locations of impacts tend to differ, even if the contacted area is the same.

1. INTRODUCTION

Fatalities of pedestrians in vehicle/pedestrian accidents (hereafter referred to as "pedestrian accidents") account for 12 to 33% (as of 1987) of all fatalities of traffic accidents in Japan, the US and Europe[1]. The United Nations, ISO, NHTSA, etc. are conducting technical studies on pedestrian accidents in recent years in order to establish standards for the protection of pedestrians, with emphasis placed on passenger cars. However, both domestic and overseas data on pedestrian accidents are rather old, which would date back to 1977 or so. The design of recent vehicle frontal shape are significantly different from those in 1977 due to the introduction of new materials for bumpers, more rounded shape of bonnet leading edge, etc., but data on recent vehicles are few. In this regard, we have analyzed national traffic accident data for a better understanding of pedestrian accidents in Japan from statistical viewpoints (age distribution of pedestrian fatalities/casualties, type of vehicle, etc.). As the second step, we have also conducted in-depth case studies on pedestrian accidents, in order to obtain sufficient and detailed data to allow specific and in-depth technical studies on the relationship between the vehicle impact and human injury (region, severity, specific details) and corresponding areas of vehicle that hit the pedestrians

(shape, location, condition of deformation), and the relationship between the shape of vehicle front portion and the injury. This report provides findings on the age distribution and vehicle types obtained by the analysis of national traffic accident data, and the relationship between the region of injury and contacted area, and the relationship between the shape of vehicle front portion and the injury per age group found through the in-depth case studies.

2. RESULTS OF ANALYSIS ON NATIONAL TRAFFIC ACCIDENT DATA

The total number of pedestrian fatalities/casualties in 1987 was 64,265 in Japan, of which the number of fatalities was 2,711. As shown in Figure 1, about 60% of four-wheelers involved in such accidents were bonnet type passenger cars or vans (hereafter referred to as "bonnet cars"). Approximately 70% of pedestrians were involved in the accidents when they were crossing roads (see Figure 2), and frontal portions of vehicles accounted for 70% or so of the portions with which the pedestrian collided against (Figure 3).

The findings are similar to those reports prepared by the EEVC Committee[2] and Ashton et al[3]. The age group of 0 to 15 accounts for 42% of pedestrian fatalities/casualties, and the age group of 60 years or older accounts for 52% of the fatalities (Figure 4). According to the EEVC report[2], many casualties (43 to 56%) are found in pedestrians of 15 to 64 years old. Many of the fatalities (42 to 49%) are also found in the same age group in France and UK, while 64 years or older account for the highest percentage (42 to 49%) in Germany, Holland, Italy and Sweden.

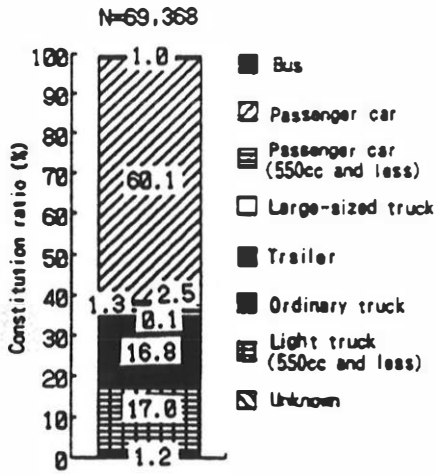


Figure 1 Constitution ratio of vehicle type (1987).

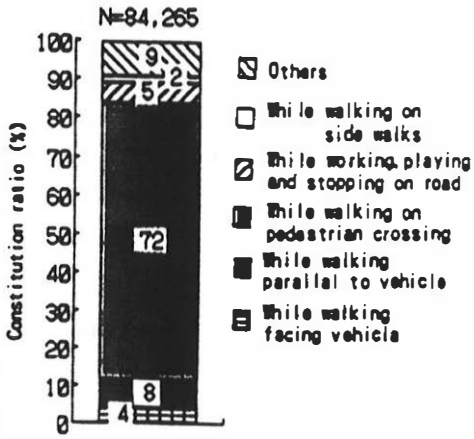


Figure 2 Constitution ratio of action of pedestrian prior to impact.

3. FINDINGS OF IN-DEPTH CASE STUDIES

In-depth case studies and analysis have been carried out on traffic accidents that involved 113 pedestrians who collided against the frontal portion of vehicles, in order to obtain sufficient accident data to allow specific and the

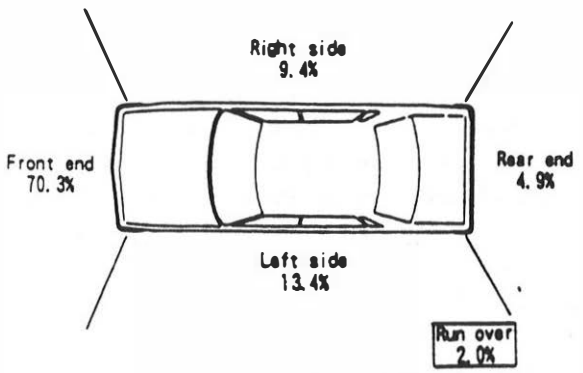


Figure 3 Location of primary impact for cars in pedestrian accidents.

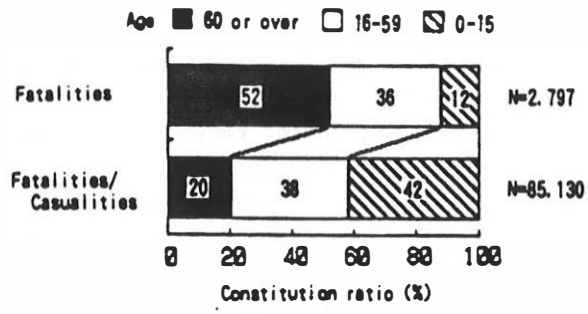


Figure 4 Constitution ratio of pedestrian age group by casualities and fatalities.

in-depth technical studies on the relationship between the region of pedestrian injury and the contacted area of vehicle, and the relationship between the shape of vehicle frontal portion and the injury per vehicle impact speed. The total number of injuries of 113 pedestrians is 425 (see Table 1), which are classified by the AIS-85[4]. The total number of pedestrians with injuries rated as AIS1 or 2 is 57, that of AIS3 or 4 is 32, and that of AIS5 or 6 is 24.

Table 1 Number of pedestrian injuries related to contact location and body region.

Contact location \ Body region		Head	Face	Neck	Chest	Abdomen	Pelvic	Arms	Legs: Overall	Femur	Knee	Lower leg	Foot	Sub-total	Total
Part of the vehicle	Front bumper	*				2	1		1	18	29	30	1	79	82
	Top surface of bonnet and wing	38	5	1	9			22							75
	Leading edge of bonnet and wing			1	2	7	20	6		16				16	54
	Windscreen glass	9	6	1				1					1	1	18
	Windscreen frame and a pillars	8	3					2							13
	Others	1	3				1	6	1	2	2	2	6	14	25
	Sub-total	56	17	3	11	9	22	37	2	38	31	33	8	112	267
Indirect contact injury				12			2	3		2			4	6	23
Road surface contact		22	20		10	3	4	34	3	3	20	1	10	37	130
Unknown								2				1	2	3	5
Total		78	37	15	21	12	28	76	5	43	51	35	24	158	425

3-1 Conditions of Injuries per Regions

Leg injuries account for the highest rate (37%) as shown in Figure 5, followed by head injuries (27% including facial injuries) and arm injuries (18%). The incidence rates are nearly the same between different age groups (see Figure 5). According to the classification by AIS rating, injuries of AIS1 or 2 are found in the leg region (34%) more than any other region, while those of AIS5 or 6 are found in the head (80%) more than any other region (see Figure 6). Component ratios of AIS classified by age groups showthat the incidence rate of AIS5 and 6 injuries is higher (13%) for pedestrians aged 60 years or older, compared with other age groups (Figure. 7).

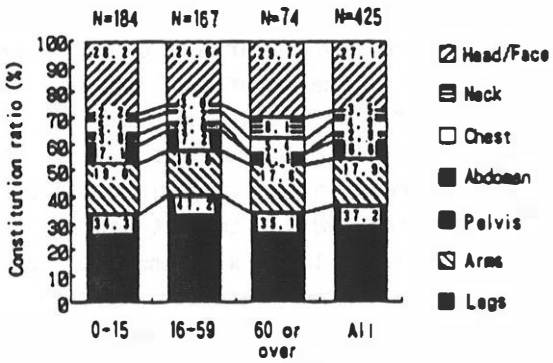


Figure 5 Constitution ratio of injury region by age group.

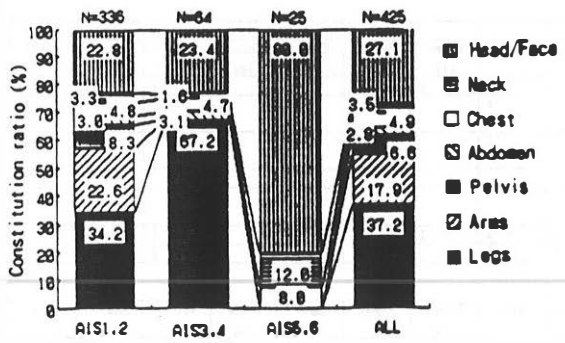


Figure 6 Constitution ratio of injury region by AIS Group.

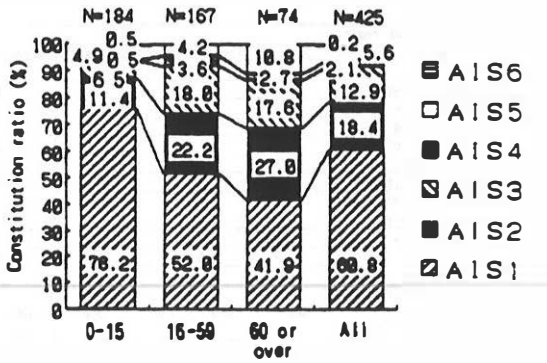
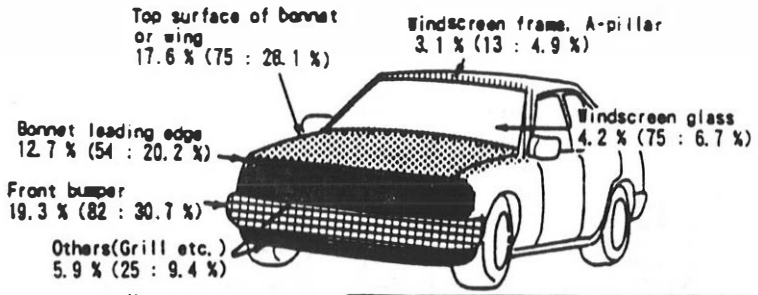


Figure 7 Constitution ratio of AIS by age group.

3-2 Cause of Injury

Injuries caused by impacts against vehicles have a higher rate (63%) than injuries caused by impacts against road surfaces (31%) as shown in Figure 8. As for the contacted area of vehicle, front bumpers account for the highest rate (31%), followed by top surface of bonnet (28 % , including wing), bonnet leading edges (20%), windscreens (7%) and windscreen frames (5%).



Number of pedestrians	113
Number of all injuries	425
Caused by vehicle contact	62.8 % (267 : 100 %)
Caused by road surface contact	30.6 %
Unknown	1.2 %

Figure 8 Constitution ratio of cause of injury

3-3 Relationship between Region of Injury and Contacted Area of Vehicle per Age Group

The relationship between the region of injury and the contact area of vehicle per age group (classified into children of 0 to 15 years old, and adults of 18 years or older) is shown in Table 2. As for cause of head injuries, the top surface of bonnet (including wing) shows the highest rate for children, while the area between the top surface of bonnet and the windscreen (including windscreen frames) shows the highest rate for adults. For neck injuries, indirect contact injuries and the top surface of bonnet account for the highest rate for children, while indirect contact injuries account for the highest rate for adults. For chest injuries, impacts against the top surface of bonnet and the bonnet leading edge account for the highest rate for children, while impacts against the top surface of bonnet account for the highest rate for adults. For femur injuries, front bumper are the greatest cause for children, while front bumper and bonnet leading edges are the greatest causes for adults. Front bumpers account for the majority of causes for knee and leg injuries for both children and adults. As described so far, contacted areas are different between children and adults even if the region of injury is the same, and locations of impacts are also different even if the contacted area is the same.

Table 2. Number of pedestrian injuries related to contact location and body region (15 or less and 16 or over).

[15 or less]

Contact location \ Body region		Head	Face	Neck	Chest	Abdomen	Pelvic	Arms	Legs: Overall	Femur	Knee	Lower leg	Foot	Subtotal	Total
Part of the vehicle	Front bumper					2	1		1	12	13	5	1	32	35
	Top surface of bonnet and wing	29	4	1	4			8							37
	Leading edge of bonnet and wing			1	2	4	9	5		3				3	24
	Windscreen glass														
	Windscreen frame and a pillars														
	Others	1	2				1	3	1	1	2	1	1	6	13
Total		31	6	2	6	6	11	16	2	16	15	6	2	41	109

[16 or over]

Contact location \ Body region		Head	Face	Neck	Chest	Abdomen	Pelvic	Arms	Legs: Overall	Femur	Knee	Lower leg	Foot	Subtotal	Total
Part of the vehicle	Front bumper									6	16	25		47	47
	Top surface of bonnet and wing	16	1		5			14							36
	Leading edge of bonnet and wing					3	11	1		15				15	30
	Windscreen glass	9	6	1				1					1	1	18
	Windscreen frame and a pillars	6	3					3							13
	Others		1					3		1		3	5	8	12
Total		35	11	1	5	3	11	21		22	16	27	6	71	156

3-4 Impact Speeds

The higher the impact speed, the severer the injury becomes caused by impacts against a vehicle. But the same tendency cannot be found for injuries caused by impacts against road surface (see Figure 9). According to the comparison of impact speeds per severity of injury (Figure 10), it is found that injuries of AIS1 or 2 occurred at impact speeds of 10 to 45 km/h, those of AIS3 or 4 at 10 to 55 km/h, and AIS5 or 6 at 25 to 70 km/h. The impact speed observed in terms of the 50%ile is about 15 to 20 km/h for AIS1 or 2, about 25 to 30 km/h for AIS3 or 4, and about 45 km/h for AIS5 or 6. In comparison with the data of the report prepared by Ashton et al.[6], the impact speeds in terms of the 50%ile impact speed in Japan are about 5 to 10 km/h lower than those of Ashton's report. The comparison of impact speeds in terms of age group is done between pedestrians of 16 to 59 and those of 60 or older, while children are excluded from the comparison since their stature are short and contacted areas of vehicle are likely to differ from those of adults even if the region of injury is the same. If the severity of injury (rated by AIS) is the same, injuries tend to occur at lower impact speeds for 60 or older people than those of 16 to 59 years old as shown in Figure 11.

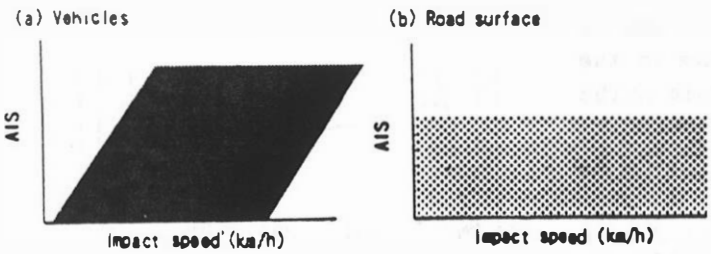


Figure 9 Relationship between vehicle impact speed and AIS (Vehicle contact and road surface contact).

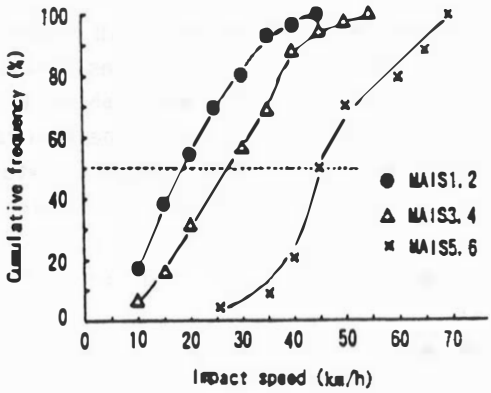


Figure 10 Cumulative frequency of vehicle impact speed and Maximum AIS.

4. DISCUSSIONS

4-1 Relationship between Stature and Head Impact Area

The top surface of bonnet accounts for the highest rate as the head impact area for children, while the area between the top surface of bonnet and windscreen (including the windscreen frame) accounts for the highest rate for adults. Since the head impact location differs by stature, it is assumed that the stature is a maximum of 131 cm for children and 150 cm or taller for adults, according to relative locations (see Figure 12) between the average height of bonnet leading edges of vehicle, obtained from to in-depth case studies (average of 530 mm to 850 mm is 730 mm ; see Figure 13) and the pelvis height of pedestrian (the height of iliosphinale is assumed as the pelvis height in this report, Figure 14). Head impact locations of pedestrians with stature up to 131 cm (to be called "children") and 150 cm or taller pedestrians (to be called "adults") tend to be divided into two areas, the front and rear portions, the rear which is behind the shock tower on a bonnet (the side closer

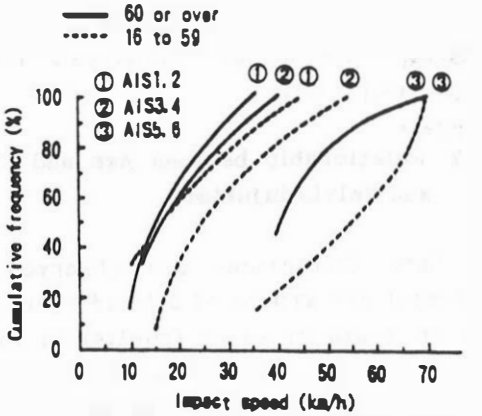


Figure 11 Relationship between vehicle impact speed and AIS by age group.

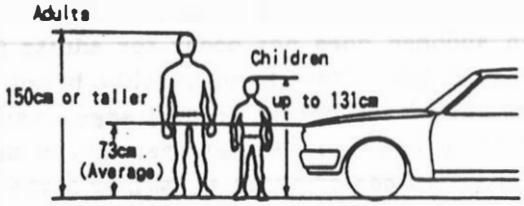
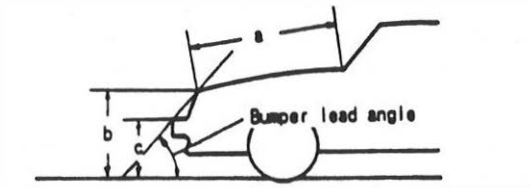


Figure 12 Classification of the stature for children and adults.



mm	Average	Maximum	Minimum
(a)Bonnet length	1164	1560	720
(b)Bonnet edge height	732	850	530
(c)Front bumber height	514	590	460

Figure 13 Average, maximum and minimum values of bonnet length, bonnet edge and front bumper height of vehicles measured of in-depth case study.

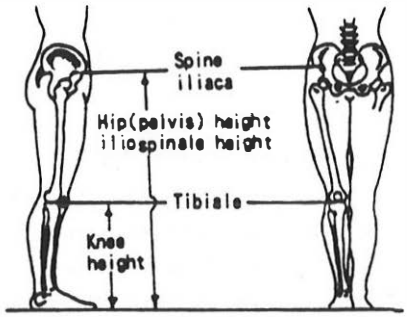
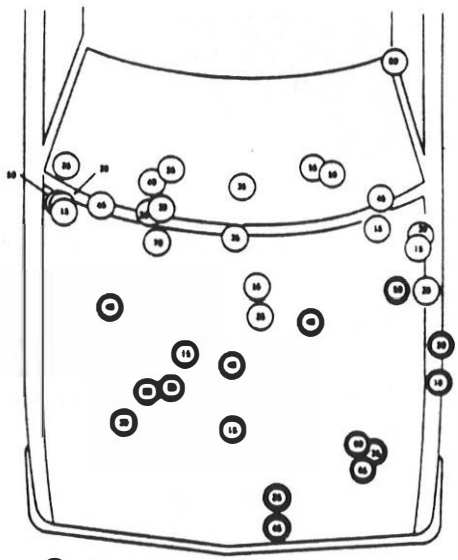


Figure 14 Hip(pelvis) height and knee height.

to the windscreen), as shown in Figure 15. Lengths of vehicles subjected to investigation are in the range of 720 mm to 1560 mm as shown in Figure 13.The distance between the head impact location and the bonnet leading edge (head impact distance) is in the range of 95 mm to 910 mm for children. In other words, the head impact locations of children fall in the two-third area on a bonnet from the leading edge. Children account for the great majority of head impacts against top surface of bonnets. For adults, on the other hand, about 60% of head impacts against top surface of bonnet are in the scuttle, and about half of the head impacts tend to concentrate on relatively solid portions such as the scuttle, bottom of windscreen frame and the windscreen itself.



● : Up to 131cm
○ : 150 or taller
Number in the circle means impact speed of the vehicle.

Figure 15 Distribution of head/face contact positions by stature of pedestrians on bonnet and other portion.

4-2 Relationship between Age and Chest, Abdomen and Pelvis Injuries

Some differences are observed between the different age groups of 0 to 15 years old (children) and 16 years or older (adults) in the severity of injury in chest, abdomen or pelvis even if the region of the injury is the same. In case of impact between the chest and top surface of bonnet, the injury tends to become severer for adults than for children, as shown in Figure 16a. This is presumably because the speed of secondary impacts of chest against the top surface of bonnet tends to become higher for adults due to their higher stature. The injury in abdomen does not occur for adults at lower speeds than those for children as shown in Figure 16b. This is presumably because the abdomen location of adult is higher than the height of the bonnet leading edge, which prevents direct impacts between them. In case of AIS3 injuries or severer (peritoneum damage, rupture of bladder, etc.) that occurred at impact speeds of about 45 km/h or higher, legs were apt to be caught by the front bumpers on the primary impacts against them and dragged in the vehicle running direction due to high impact speeds. Therefore, the amount of parallel travel of pelvis was increased, then the

pelvis dropped downward, both caused by the secondary collision against the bonnet leading edge. In case of pelvis injuries, bone fractures (AIS2) are found in adults than in children as shown in Figure 16c. This is presumably due to the fact that many children were hit nearly sideward around the pelvis, while adults were hit around the lower region of the pelvis (region near the hip joint) by the bonnet leading edge due to their higher stature, causing the fracture of pubis or ischii. Injuries in abdomen and pelvis with severities of AIS3 or higher tend to have lower incidence rates than those of the EEVC report[6].

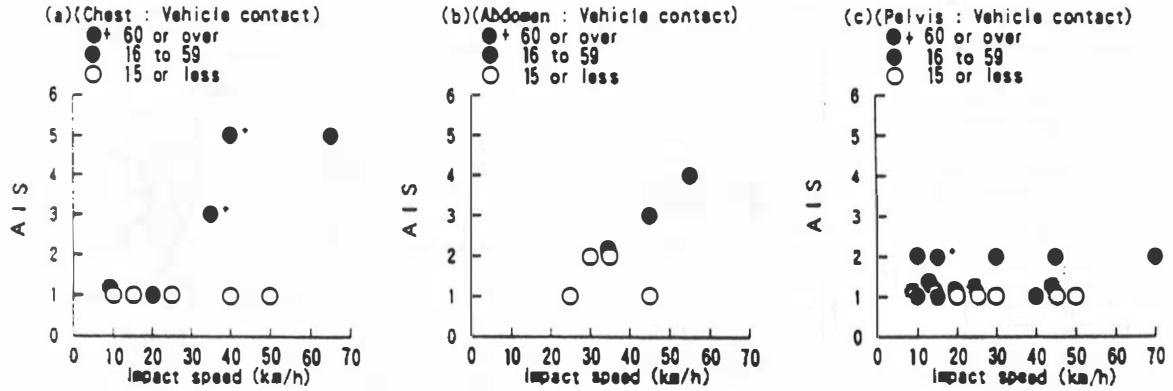


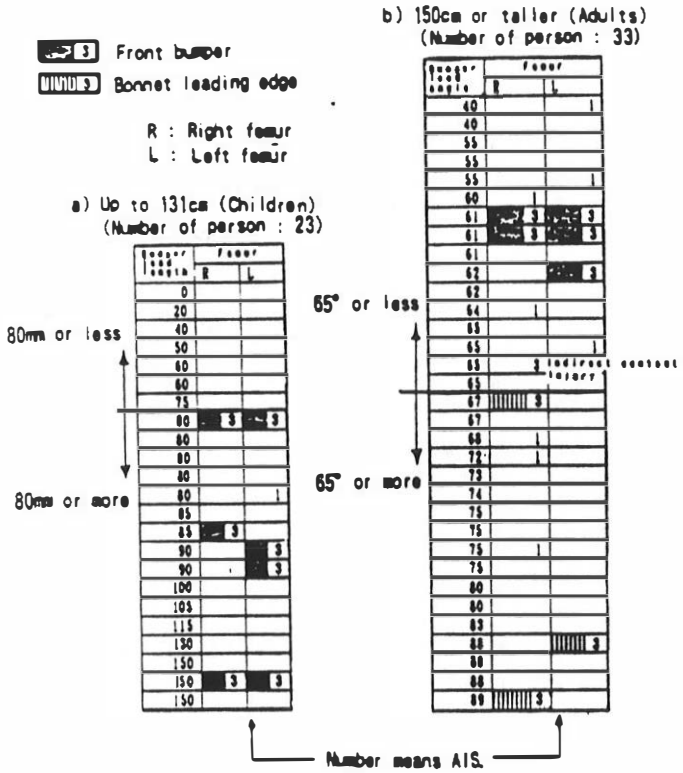
Figure 16 Relationship between vehicle impact speed and injury severity of body region (chest, abdomen and pelvis) imposed by vehicle contact for age age group (15 or less, 16 to 59 and 60 or over) of pedestrians.

4-3 Leg Injuries and Vehicle Frontal Shape

Stature of pedestrians were divided into two categories, up to 131 cm (children), and 150 cm or taller (adults), and the relationship between the bumper lead (bonnet lead) length or angle and the fracture of femur or lower leg, or the injury of ligament were investigated. Femur fractures (AIS3) of children tend to occur where the bumper lead exceeds about 80 mm (See Table 3 and Figure 17). For adults, on the other hand , the front bumper tends to become the area of contact where the bumper lead angle (see Figure 13) is 65° or less, while the bonnet leading edge tends to become the area of contact where the bumper lead angle is 65° or greater. For children, the tendency of femur fractures may be described as follows ; when the bumper lead is long, the impact load tends to concentrate on the impacts between the bumper and femur as shown in Figure 17a, which causes the incidence of femur fracture. When the bumper lead is short, impacts on the human body (near pelvis) occurs not only against the bumper but also against the bonnet leading edge, grills, etc. almost simultaneously. These disperse the impact force and reduce the incidence rate of femur fracture itself. In case of adults, the impact load tends to concentrate on the collision between the bumper and femur where the bumper lead is long as shown in Figure 17b, the same as in the case of children. When the bumper lead is short, impacts against not only the bumper but also against the bonnet leading edge, grills, etc. would occur almost simultaneously. These should have reduced the femur fracture incidence rate, but the incidence rate does not drop markedly as the impact load concentrates on the secondary impacts of femur against the bumper leading edge when the hips travel parallelly and the torso falls on the bonnet. This tendency is similar to that of Ashton's report[6]. Injuries of knee ligament (AIS3) found only in adults do not show any relationship with the bumper lead length or angle, but the bumper height appears to affect knee ligament injuries since the height of bumper and the height of knee are about the same. Lower leg bone fractures (AIS2 or 3) are not found in the children, and do not show any relationship with the bumper lead length or angle for adults either. As lower leg bone fracture are found even when the impact speed is as low as 15 km/h, the posture of pedestrian - e.g., whether or not the

weight of the pedestrian is applied into the legs at the moment of impacts - appears to affect the incidence of lower leg injury. Similar to the report[7] prepared by Cesari, et al., ligament injury and bone fracture did not occur simultaneously.

Table 3 Relationship between fracture of femur and bumper-lead length, bumper-lead angle in pedestrian of height up to 131cm and 150cm or taller.



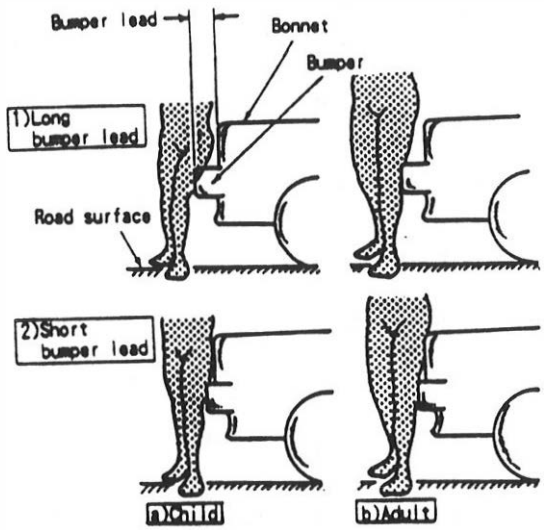


Figure 17 Comparison of impact pattern for children and adults (long bumper lead and short bumper lead).

5. CONCLUSIONS

Pedestrian accidents were analyzed from a purely statistical viewpoint, according to the national traffic accident data in Japan and from a detailed standpoint based on the findings of in-depth case studies for the safety of pedestrians.

(1) Approximately half of pedestrians involved in fatalities/casualties of traffic accidents are in the age group of 0 to 15 years old, and about half of pedestrian involved in fatalities are 60 years or older.

(2) About 60 % of four-wheelers involved in pedestrian accidents are bonnet type cars.

(3) About 70 % of the pedestrians were hit by vehicles while they were crossing roads.

(4) About 70 % of the pedestrians were hit by the front portions of vehicle.

(5) There are more injuries of pedestrians caused by vehicles than those caused by road surfaces.

(6) Many of the injuries are found in the head against caused by impact the top surface of bonnet, and in the leg against frontal bumpers.

(7) Head impact locations of children and adults are divided mainly into front and rear areas on the bonnet behind the front shock tower. Children account for the majority of head impacts against top surface of bonnet, as their impact locations fall in the two-third of area between the bonnet leading edge and the rear of the shock tower. Head impact locations of adults tend to concentrate on relatively solid portions such as the scuttle, bottom of windscreen frame and the windscreen itself.

(8) Injuries in the chest, abdomen and pelvis of adults tend to become severer than those of children, even if the impact speed is the same.

(9) Femur bone fractures of children are found when the bumper lead length exceeds about 80 mm. For adults, bumpers are the area of contact when the bumper lead angle is 65° or less, while the bumper leading edge is the area of contacted when the bumper lead angle exceeds 65° .

As described so far, it is vital to take adequate account of difference in stature between adults and children for the protection of pedestrians against vehicles. This is because the area of contact may differ even though the region of injury is the same. Similarly, the impact location may also differ even though the contacted area of vehicle is the same.

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