

A Study of Elderly Pedestrian Injury Patterns in KIDAS

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Abstract: Since the pedestrian safety test procedures were published in the 1990s, the ULF-BLE test has been frequently criticized as not being representative of the real-world accident scenario or the injury mechanisms in pedestrian-to-vehicle accidents. But, recently, EuroNCAP updated the upper legform test protocols for the vehicle has lower bumper reference line is greater than 500mm vertically above the ground. But the majority of pedestrian victim's ages of domestic traffic situations are more than 50 years old which average height is smaller than Europeans. To protect pedestrian from traffic accidents, Korea has been continuously reinforced vehicle safety regulation and KNCAP. Especially, the overall rating system in KNCAP, the weighting factor of safety performance of pedestrian is 25%. But, in the real road, the fatalities involved car-to-pedestrian accidents were 1,843 which is about 40% of all traffic related deaths in 2014. Also, from the police reported data, the pedestrian accidents were 50,315 cases. However, from the integrated traffic accident data (police reported data and insurance claimed data), severely injured pedestrians were 39,376 and minor or moderately injured pedestrians were 62,764. In this study, the collected 177 cases of adult pedestrian accidents from KIDAS were investigated to explore the injury severity of body regions as well as age related injury patterns. Not only injury of head and lower leg, injury of all other body regions were examined. Particularly, the injury of abdomen and pelvic areas were closely examined. The main objective of this study is establish the upper legform test with consideration of domestic pedestrian accident data as well as anthropometric data to protect elderly pedestrians that the average physical status is less weight and shorter than western adults.

Keywords: Elderly pedestrian, Upper legform test, Pelvis injury, KIDAS, Injury severity

1 Introduction

There are many variables in a vulnerable road user traffic accident that will affect the injury severity of the people involved. These include factors related to the casualty (age, gender, biomechanical tolerance, walking positions and directions, etc.), factors related to the vehicle (size, shape, impact speed, effectiveness of absorbing impact energy, etc.), and factors related to the wider environment (characteristics of the object hit, effectiveness of the medical treatment, etc.). All these variables have an important relationship to the likely injury severity of the casualty.

The pedestrian safety testing methodology was initially developed by EEVC (European Enhanced Vehicle-Safety Committee) working groups. It consists of three subsystem tests: headform to bonnet test; upper legform to bonnet leading edge test and lower or upper legform to bumper test. Since the pedestrian safety test procedures were published in the 1990s, the upper legform test has been frequently criticized as not being representative of the real-world accident scenario or the injury mechanisms in pedestrian-to-vehicle accidents [1–4]. In 2013/2014, Euro NCAP discussed modifications to the test procedure. However, the aim of short-term improvement restricted the amount of possible modifications. Essentially, the impact location and speed were changed for the updated test protocol of January 2015.

Various studies analyzing pedestrian accidents were published with or without aid of AEB system on the vehicle recently. Most statistically enhanced analysis is based on the GIDAS (German In-Depth Accident Study) [5, 6] or PCDS (Pedestrian Crash Data Study of the NHTSA) databases [7]. Lower extremities are commonly summarized in one group (according to AIS body regions), without distinction of pelvic, femoral, knee or lower thigh injuries. Several risk factors associated with pelvic and femoral injuries have been reported in literature: age and gender of the pedestrian, vehicle geometry and impact speed,

Demetriades et al. [8] found within a trauma registry study that pelvic fractures were significantly more common for elderly pedestrians (6.8% for pedestrians younger than 14 years compared to 9.8% for 65+ years). Also, gender and pedestrian body height were found to influence impact kinematics and the risk of sustaining pelvic injuries [9-10]. The main objectives of this study was to find key parameters based on accident analysis that are relevant for pedestrian injury mechanics due to age and height or domestic pedestrian accident environments, especially pelvic and upper femoral injuries [11], which should be taken into account in future analysis and possible improved pedestrian safety policy in Korea such as regulations and KNCAP test protocols.

2 National pedestrian accidents data

From the integrated police report (police, insurance etc.) which counted all injury involved road traffic accident in 2014, the total numbers of pedestrian accidents were 167,264 cases. The fatality of pedestrians were 1,843 persons (within 30 days' death), and 39,376 persons were severely injured. The minor or moderately injured pedestrians were 62,674 and the numbers of pedestrians who claimed or reported that he or she was injured during the pedestrian-vehicle related accidents were 63,371 as shown in table 1.

Table 1. National pedestrian accident data (2014)

Age	Injury Severity	Total	Male	Female	Age	Injury Severity	Total	Male	Female
21-30	Fatality	79	55	24	51-60	Fatality	350	245	105
	Sever Injury	3,516	1,903	1,613		Sever Injury	7,667	3,531	4,136
	Minor Injury	8,483	4,278	4,205		Minor Injury	11,907	5,331	6,576
31-40	Injury Report	8,636	4,874	3,762	61-64	Injury Report	11,009	6,014	4,995
	Fatality	113	92	21		Fatality	119	61	58
	Sever Injury	3,489	2,149	1,340		Sever Injury	2,475	960	1,515
41-50	Minor Injury	7,510	4,281	3,229	65이상	Minor Injury	3,279	1,369	1,910
	Injury Report	7,586	4,619	2,967		Injury Report	2,931	1,447	1,484
	Fatality	221	181	40		Fatality	898	332	566
	Sever Injury	5,182	2,959	2,223		Sever Injury	11,032	3,379	7,653
	Minor Injury	9,655	5,074	4,581		Minor Injury	10,058	3,639	6,419
	Injury Report	9,595	5,645	3,950		Injury Report	8,326	3,853	4,473

From above table, 49% of pedestrian fatality came from the more than 65 year's old adults. In this age category, total 898 elderly pedestrians were killed by traffic accidents. The female victim of elderly pedestrian was about 63% compared to male victim. However, other age groups, the majority of victim were male pedestrians. The ratio of sever injured elderly pedestrian (65+) was 53.8% and the minor injury ratio was 42%. The total ratio of fatality for the more than 51 year's old pedestrian victim (51+) was 70.3% (1,367 killed). In this age group (51+), 53% of fatal victim was female pedestrians.

Table 2. National police pedestrian Injury body data (2014)

2014	Total	Head	Face	Neck	Chest	Abdomen	Back	Pelvis	Upper Ex.	Lower Ex.	N/C
Fatality	1,843	916	142	35	160	58	3	54	2	159	314
Ratio (%)	100.0	49.7	7.7	1.9	8.7	3.1	0.2	2.9	0.1	8.6	17.0
Injured	51,590	3,726	2,030	2,199	1,667	193	149	7,065	3,704	17,963	12,894
Sever	23,657	2,272	1,164	709	1,229	91	55	2,902	866	8,706	5,673
Minor	25,005	1,337	756	1,430	397	81	81	3,880	2,516	8,198	6,329
Injury Report	2,928	117	110	60	41	21	13	283	332	1,059	892
Ratio (%)	100	7.2	3.9	4.3	3.2	0.4	0.3	13.7	7.2	34.8	25.0
Sever Ratio (%)	100	9.6	4.9	3.0	5.2	0.4	0.2	12.3	3.6	36.8	24.0

According to the police only statistical data (Table 2), the major cause of fatality is head injury. More than 50% (head, face and neck) of all pedestrian injury is head contact to vehicle or road surface. Second cause of death was chest injury and the followings were lower extremity and abdomen injuries. For the severe injury case, the main injury body parts were lower extremity, pelvis and head.

3 Anthropometric national data

Average height of adult Korean are varying with ages. According to national statistics which measured on 2010 from 6th SizeKorea project, age from 20 to 60 year's old male adult, average height was 1,715mm (SD 61.4 mm) the average height of female adult (20-60) was 1,586 (SD 56.2 mm). The young male adult (20-29) was 1,736 mm (SD 57.2 mm) and but elderly male adult (60-69) was 1,644 mm (SD 51.7 mm). The young female adult (20-29) 1,602 mm (SD 51.3 mm) and elderly women (60-69) was 1,523 mm (SD 53.2 mm). Compared with European average adult height which applied the current pedestrian test method (GTR and Euro NCAP), the average of Korean height of adult was about 15 - 20 cm shorter than western adults.

4 Pedestrian accidents in KIDAS

The issues of current traffic accident investigation and data collection from polices in Korea were very limited access for an individual accident event. Also, the lacks of automotive related information which police is not much concerned, are very difficult to analyze the accident involved vehicle's safety problems.

As part of Korea Advanced Safety Vehicle (KASV: 2009-2017) project, the pilot study of KIDAS (Korean In-Depth Accident Study) has been initiated in 2012 collected from in-patient of 3 regional medical school's hospitals. Once injury involved accidents occurs, the occupants may have delivered through these emergency centers. After medical treatments, the research team can search for police station for more information but, unfortunately not always successful achieving accident data from police due to the privacy protection restrictions. After collecting police's accident report or verbal information related the accident with inspection of crashed vehicle, even though the total amount of collected data is limited, can be constructed each individual accident database.

The total 230 cases of pedestrian accidents data including patients of child were collected during the 2014. In this dataset, 5 pedestrian victims (2.2%) were death before or after arrival of emergency room. From dataset, 119 case were adult pedestrian patients (18-64) and the elderly patients were 58 cases. The 53 cases were excluded due to under 18 year's old age.

In this study, in order to examine adult injury patterns of elderly pedestrian accidents, adult (18-64) and elderly (65+) of pedestrian patients were compared. The total adult pedestrian patients were 177 cases while the elderly pedestrian were 58 cases. The injury severities of pedestrian were categorized by ISS values as minor injury ($ISS < 9$), moderate injury ($9 \leq ISS < 15$) and severe injury ($ISS \geq 15$).

The adult pedestrian (18-64) cases were 119, with 66 cases were male and 53 cases were female patients. As shown in table 3, the male was more frequently involved in the pedestrian accidents than female adults. This result may indicate that adult male was more involvements of social life. The national data (table 1) also shows the similar trends, more frequent accident involvement of male than female adults.

Table 3. Adult (18-64) pedestrian accidents KIDAS data

Case	ISS		
	1-8	9-15	15-75
Adult(119)	62 (52.1%)	22 (18.5%)	35 (29.4%)
Male (66)	36 (54.5%)	10 (15.2%)	20 (30.3%)
Female (53)	26 (49.1%)	12 (22.6%)	15 (28.3%)

The majority of adult pedestrian (18-64) injury was minor injury ($ISS < 9$) with 52.1%. It was 62 cases while 36 males and 26 female involvement of minor or slightly injured. The severe injury ($ISS \geq 15$), the second largest injury, was 29.4% (35 cases). The severe injury ratio was similar both male and female adults.

Table 4. Elderly (65+) pedestrian accidents KIDAS data

Case	ISS		
	1-8	9-15	15-75
Adult(58)	21 (36.2%)	15 (25.9%)	22 (37.9%)
Male (17)	6 (35.3%)	5 (29.4%)	6 (35.3%)
Female (41)	15 (36.6%)	10 (24.4%)	16 (39.0%)

However, the trends of the elderly pedestrian accidents were opposite. Even though, the collected elderly data is limited (58 cases), the elderly female pedestrians were more involved in the traffic accidents. The ratios of injury severity were similar in both male and female patients. From the national pedestrian accident data, the victims of elderly female were more than 2 times of those of elderly males. The KIDAS shows the similar patterns of elderly pedestrian accidents.

Another difference of the elderly pedestrian compared adult pedestrian patients was severity of injury. For the adult cases, more than 50% of patients were experienced the minor injury ($ISS < 9$). But the elderly pedestrian case, the minor injury was 36.2%. The moderate injury ratio was 25.9% and 37.9% of severe injury ratio.

5 Results and discussions

The total 230 cases of pedestrian accidents data were collected during the 2014. In this dataset, 5 pedestrian victims (2.2%) were death before or after arrival of emergency room. The severely injured patients who deliver to the intensive care unit after first treatment from emergency room were 56 cases (24.8%). The others were either minor injury (out-patients) or moderate injury (in-patients). In the age distribution, 53 patients were under 18 years' old and the remaining 177 cases were adult (18+) pedestrian patients. The average adult (18+) patients age was 56.3 and standard deviation was ± 17.5 as shown in figure 1.

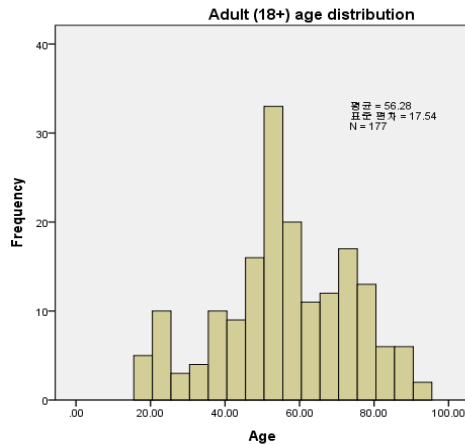


Figure 1. Age distribution of adult (18-64) pedestrian

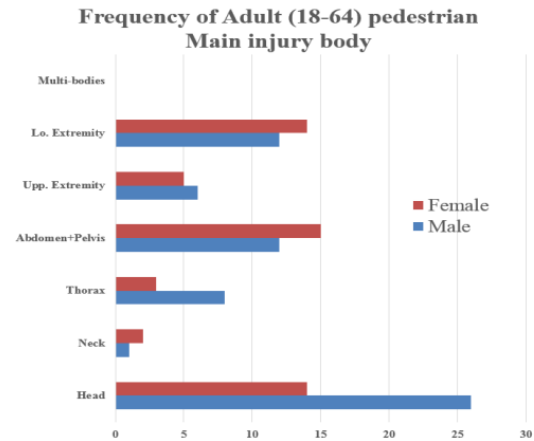


Figure 2. Frequency of adult (18-64) pedestrian main injury body

From analysis of main cause of injury body parts for adult(18-64) patients, the head injury was most dominant cause of injury, male case 39.4% and 26.4% for female adults as shown in figure 2 and table 5.

The lower extremity such as lower leg and abdomen and pelvis injury were followed as frequent injured body parts.

Table 5. Adult (18-64) pedestrian main injury body case

	Male (66)	Female (53)	
Head	26	14	
Neck	1	2	
Thorax	8	3	
Abdomen+Pelvis	12	15	
Upp. Extremity	6	5	
Lo. Extremity	12	14	
Multi-bodies	0	0	
	Average	Average	Average
	Height	Weight	Age
Adult (18-64)	169.2cm	67.4kg	46.8 Yo
Male	171.1cm	69.6kg	44.8 Yo
Female	161.8cm	57.5kg	49.2 Yo

The average height and weight of adult (18-64) pedestrian patients were 169.2cm and 67.3kg respectively which is below the average of those of Europeans that guideline for development of pedestrian protection regulation, GTR.

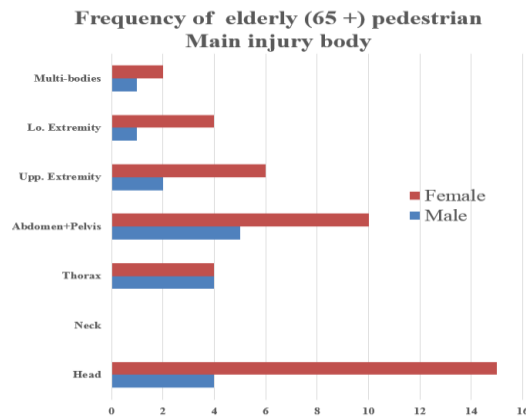


Figure 3. Frequency of elderly (65+) pedestrian main injury body

The main injured body part of elderly pedestrian was different from adult. The head injury is also major cause of injury but the frequency of abdomen and pelvis injury is higher than other age groups. As shown in Table 6 and figure 4, the average height of male was 166cm and female was 152.8cm that is similar to 5%tile of western adult female. The different heights between Asian and European can distinguished injury patterns, especially female and elderly pedestrians.

Therefore, with increasing sale volume of SUV type vehicles and the current Euro NCAP's upper legform test with WAD 775cm may not be protectable for smaller status adult, especially Asian and elderly peoples.

Table 6. Elderly (65+) pedestrian main injury body case

	Male (17)	Female (41)	
Head	4	15	
Neck	0	0	
Thorax	4	4	
Abdomen+Pelvis	5	10	
Upp. Extremity	2	6	
Lo. Extremity	1	4	
Multi-bodies	1	2	
	Average	Average	Average
	Height	Weight	Age
Adult (65+)	156.1cm	55.4kg	75.8 Yo
Male	166.0cm	62.4kg	76.8 Yo
Female	152.8cm	53.1kg	75.4 Yo

Age has been known to be an important factor in traffic safety, in particular regarding risk of injury for a given amount of mechanical force. Older persons have a higher risk of injury, and it is known that this risk accelerate with higher age. Also the risk of death is higher as well as the risk of long term. For passenger cars in general, the most frequently injured body regions in struck pedestrians are traditionally head, legs and pelvis.

SUV primarily affected body regions by serious injuries were head and legs, followed by pelvis and chest. Again for all passenger cars, show that serious pedestrian injury patterns in newer vehicles are moving towards thorax and pelvis injuries. The increasing importance of thoracic injuries, specifically for cyclists is a new issue. The rate of head injury decreases with age whereas the rate of hip and thigh injury increases.

The latter trend appears to accelerate from the age of 60, which the researchers attribute to the decrease in bone density and strength observed in this age group. When considering an ageing population this highlights that the compliance of the vehicle zones impacting hip and thigh gain relative importance [12].

6 Conclusion and future works

In this study, the frequency of pedestrian accidents was examined in both National integrated police data and KIDAS data in 2014 accident reports. The analysis of accident data underlies a variety of limitations, as follows:

1. This KIDAS data analysis includes only 4 local hospitals data that collected from Emergency Care Centre can't represent national pedestrian accident trends.
2. The KIDAS dataset is relatively small and all data may not have completed form
3. Limitation of access of accident scene or crashed vehicles, vehicle impact speeds and impact location of vehicle body can't be classified.

In Korea, the pedestrian accidents are major cause of traffic fatality. The characteristics of domestic pedestrian accidents are more elderly people involved accidents which show similar patterns between police and KIDAS data. Among elderly accidents, the female pedestrian is more frequently involved pedestrian-car accidents compared with other age groups. Since average height and weight of Korean elderly people is much smaller and lighter than other age groups especially comparison with Europeans. Not only shorter status but posture of during walking with bended back bone, the elderly height may much shorter than expected. Even passenger vehicle can hit the pelvis or abdomen area of elderly female pedestrians.

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