The Protections of the Elderly Vehicle Occupants: Need lower belt loading

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ABSTRACT

With continuously efforts of improving vehicle safety adopting the emerging new technologies, reduction of traffic fatality has been dramatically improved. Also the rule making bodies in globally have been contributed significantly to protect vehicle occupants and pedestrians with global harmonization activities more enhanced safety regulations and requirements.
However, until recent a few years, the protections of vulnerable vehicle occupants, such as elderly drivers or passengers were not focused in the main stream of vehicle safety issues.

In globally, most of developed countries are either aged or aging societies. The fatality of elderly occupants (65 years old or more) rapidly increased in Korea. In 2010, while the fatality rate (per 1,000 accidents) for all age group was 24.3 deaths, but elderly vehicle occupant fatality ratio was 43.3. The major sources of elderly occupant fatality were come from the thoracic injuries.

In this paper, the average size of Korean elderly morphemic figure was investigated and developed the Koran elderly anthropometric models to assess kinematics of occupants and injury mechanism. Based on the existing injury risk curves, the injury risk curves of Korean elderly occupant and Korean elderly version of Hybrid III were developed. With scale methods, their injury risks were converted to the standard Hybrid III injury measurements.

With the developed injury risk curves, the probability of AIS 3+ injury of 50%, 20%, and 5% for 45 years old adult male (50th percentile) case, the rib deflections are 91.6mm, 73.28mm and 50.38 mm, respectively. For the Korean elderly case, the rib deflections are 77mm, 59.4mm and 37.4 mm, respectively. As the results, the current Hybrid III structure especially thoracic body is not good enough to assess the elderly thoracic injury.

The other additional requirements, such as limiting seat belt forces were recommended. The main sources of fatality or sever injury for elderly in vehicle occupants are from thoracic injuries due to aging effects of rib cage structures. Since the current Hybrid III's thoracic structure are stiffer than a human body, the more stringent rib deflection injury criteria may result the higher belt loading to the elderly rib cage.

INTRODUCTION

Already in 2000, Korea was in the stage of aging society with the 7.2% of elderly population. As rapidly increasing older age group, 65 years old group reached 11.4% in 2011 and it will be estimated entering aged society in 2017 with 14.0%. In 2026, elderly group will be reached up to 20.8% as the super aged society. The driver license for older age group was only 0.5% of the total driver license holding age group in 2001. But, the annual increase ratio of elderly driver is 14.9% compared 3.2% increasing ratio of total driver licenses.

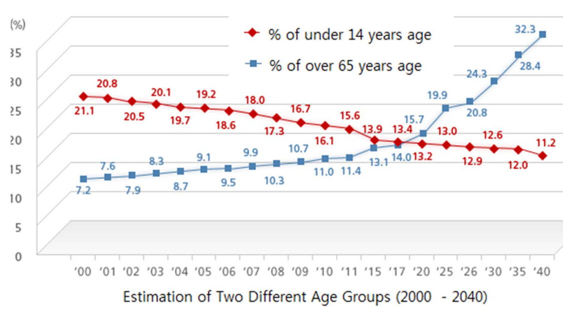

Figure 1. Trends of two different age groups

As other countries, in general, the overall traffic accidents are continuously decreased. In 2011, the total number of accident in Korea was reduced 14.9 % compared with 2001. The numbers of elderly driver involved accidents were only 3,768 in 2001, but with continuously increased the numbers of elderly driver accidents it was reached 13,596 in 2011. During the 10 years period, the elderly driver involved numbers of accidents were increased more than 360%. As shown in figure 2, in same period of time, the fatality ratio of elderly driver was increased 260%. The injury ratio was increased 380%.

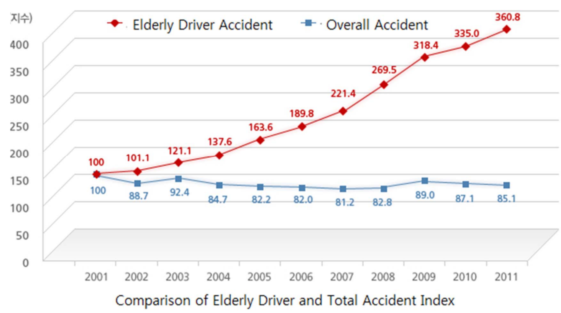

Figure 2. The annual trends of elderly driver involved traffic accidents

The percentage of elderly driver involved accidents was only 1.4% in 2001. In 2005, it was reached 2.9%. With continuously increased, in 2011, the percentage of elderly driver involved accidents was 6.1% of the total number of accidents. During 2001 to 2011 time period, the average fatalities per 100 accidents were 2.8 persons but, the fatalities per 100 accidents for the elderly driver was 2 times higher than the average fatality ration. It was 6 persons per 100 accidents as shown in figure 3.

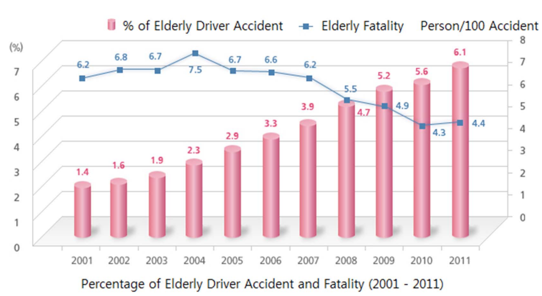

Figure 3. The Fatality ratios of elderly drivers

KOREAN ELDERLY OCCUPANT INJURY CHARACTERISTICS

The accident database of an insurance company was statistically evaluated to examine the elderly occupant's accident patterns and injury types. The total 64,424 car-to-car type frontal accidents was scanned but injury involved 32,195 accidents (injured person: 61,645) was collected as 1st data set. After eliminate the improper data not provide sufficient information, the final data set was targeted 26,057 injured accidents.

The data was categorized 4 different age group, such as less than 25 year old, 25 year to 54 year, 55 year to 64 year and 65 year and older. The injury characteristics were classified by 9 AIS injured body segment classes. The 3 highly injured body parts compared with other age groups were carefully investigated to find any statistical significant.

From results, the elderly occupants exposed higher risk in thorax, head and abdomen. The thoracic injury risk is 2.6 time higher than other ages. The head injury is 1.3 time higher and abdomen injury is 1.9 time higher. The male elderly's abdomen injury is 26.2% higher than that of female elderly occupant. But, female elderly has higher potential risk in head and lower extremity 57 % and 11.6 % respectively more than those of male elderly. In seating position, driver side is 2.9 times more suffered thorax injury compared with 25 - 54 year old age group. The elderly occupant seated in front passenger seat or rear seats reveals 1.4 - 1.8 times higher injuries in abdomen and lower extremity as well as thorax injury.

Regardless the type of vehicles, the thorax injury of the elderly occupant is more than 1.7 - 2.1 times more frequently occurred. The elderly seated in SUV and RV vehicles are more injured than sedan type vehicle during the car-to-car frontal collisions. The seat belted elderly is more suffered thorax, abdomen and upper extremity injuries than other age groups. However, compared with no-belted occupants, there are no differences in terms of injury between different age groups. Even the airbag equipped vehicle, still elderly occupants exposed 12.9% more sever thorax injury compared with other age group

Table 1 Injury Patterns with Different Age Group in Car-to-Car Frontal Accidents

	MAIS 3↑				MAIS 2↓			
Age	~ 24	25~ 54	55~ 64	65 ~	~ 24	25 ~ 54	55 ~ 64	65 ~
Head	28	194	34	20	736	4,316	505	220
Neck	52	420	84	37	2,078	11,719	1,265	473
Lumber	19	219	47	27	179	1,142	136	55
Thorax	25	325	55	41	14	1,91	36	24
Abdomen	37	192	31	21	59	212	29	21
Arm	53	402	54	40	316	1,613	156	87
Leg	41	244	33	21	177	810	83	38
Whole Body	21	86	18	14	45	275	30	13
Total	227	1,408	246	153	3,508	19,314	2,248	987

LITERATURE REVIEW - INJURY OF THE ELDERLY OCCUPANTS

The risk curve, based on serious casualty data, exaggerates older drivers' crash involvement because of the 'frailty bias'. Because older people are more readily injured by a given physical impact, proportionally more of their total crashes have serious casualty outcomes. Many of research suggest that around one-half of the heightened fatality risk of drivers aged 75 years and more might be due to frailty rather than to unsafe driving practices. The same correction can be made to older drivers' involvement in non-fatal serious injury crashes.

Aging is a complex process which yields numerous mental and physical changes. In the present study, only physical changes were considered (e.g., geometrical, material, and structural). A number of studies have shown that, with increasing age, the energy-absorbing capacity of body structures generally declines. Burstein, Reilly, and Martens concluded that there was a 5% decrease in the fracture strain per decade in the femur and a 7% decrease for the tibia. Zhou, Rouhana, and Melvin reviewed a number of aging functions of the femur bone and showed that the maximum bone strength occurs at approximately 35 years of age. The bone strength then begins to decline, with the rate of decline increasing significantly after 60 years of age. Zhou et al. also determined that the human soft tissues follow a similar trend.

Although older drivers are involved in relatively few collisions due to limited exposure, once involved in a crash they are more likely to sustain severe injuries or death (Cunninghan *et al.*). Several studies have confirmed that as people age, they are more likely to sustain serious or fatal injuries from the same severity crash (Evans, Evans, Bedard *et al.*, Mercier *et al.*, University of Michigan, Wang, Peek-Asa *et al.*, Li *et al.*).

Elderly drivers and occupants are especially at risk of thoracic region injuries due to increased bone fragility (University of Michigan, Wang *et al.*, Wang, Augenstein *et al.*, Foret-Bruno, Schiller, Sjogren *et al.*, Bulger *et al.*). Results from S.C Wang, the head injury is the most frequent in younger age group, while the older age group is suffered from mostly thoracic injury as shown in Figure 10. From the NASS (1993-1996) data, the more old age group, the more numbers of rib fracture is occurred in the frontal collision.

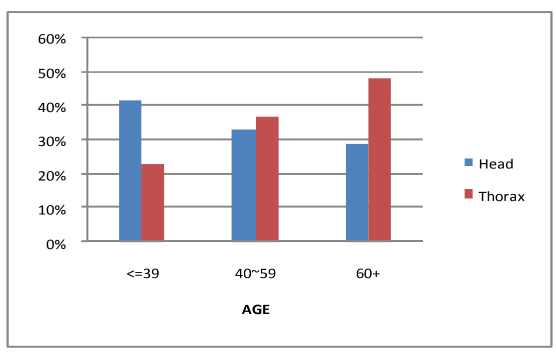

Figure 4. Incidence of Thoracic and Head Injury by Age Group. (S. C. Wang).

Results from Trosseille researches, the chest injury risk of AIS+3 for 40 year old occupants reveal less than 10% up to 6kN of shoulder belt force. However, the risk is dramatically increased. For the same level of shoulder belt force, 50 year old can be exposed 35% of risk and for 70 year old occupant, it can be reached up to 95% of AIS+3 thoracic injury.

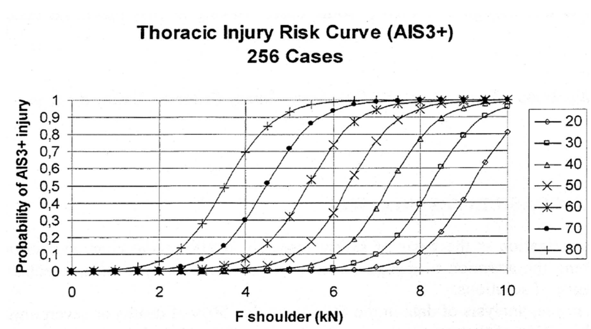

Figure 5. Probability of severe thoracic injuries (AIS3+) depending on the shoulder belt force and the occupant age (Trosseille)

SLED TEST WITH THE VARIOUS IMPACT SPEEDS.

A series of sled test was conducted to check the belt loading forces in the Hybrid III 50%tile male dummies with the various impact speeds as shown in Figure 6 and Table 1.

Figure 6. The sled test set-up with the various impact speeds in different types of load limiters.

The impact speeds were selected 56kph as KNCAP test speed, 48 kph for regulation test. Since the most frequent accident speeds for the elderly drivers was less than 40kph, the test speed was selected 40 kph. In this test, 5 different types of belt load limiters were used to measure the dummy belt forces.

Table 2. The sled test conditions

Test No.	Vehicle	Dummy	Impact Speed	Seat belt spec.
T1	A Type-1	Hybrid 50%tile	56km/h	(2.5kN) Single
T2	〃	〃	48km/h	〃
T3	〃	〃	40km/h	〃
T4	A Type-2	〃	56km/h	2.0 kN Single
T5	〃	〃	48km/h	〃
T6	〃	〃	40km/h	〃
T7	A Type-3	〃	56km/h	2.0 kN Single
T8	〃	〃	48km/h	〃
T9	〃	〃	40km/h	〃
T10	B Type-1	〃	56km/h	4.0 kN Single
T11	〃	〃	48km/h	〃
T12	〃	〃	40km/h	〃
T13	B Type-2	〃	56km/h	4.0 kN Single
T14	〃	〃	48km/h	〃
T15	〃	〃	40km/h	〃
T16	C Type-1	〃	56km/h	1.5kN Single
T17	〃	〃	48km/h	〃
T18	〃	〃	40km/h	〃
T19	C Type-2	〃	56km/h	(2+2kN) DLL
T20	〃	〃	48km/h	〃
T21	〃	〃	40km/h	〃

As shown in Figure 7, while the higher impact speed shows some indication of increasing thorax force levels, but in general, the shoulder belt forces were not strongly influenced by the different impact speeds.

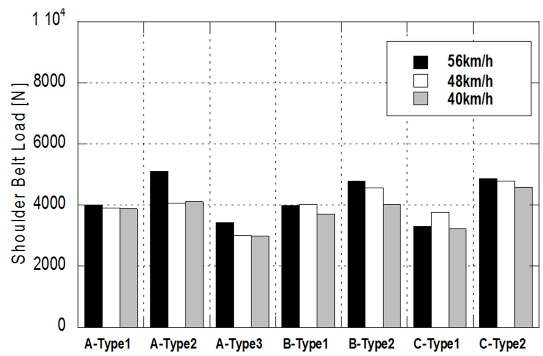

Figure 7. The shoulder belt forces in different impact speeds

However, the lap belt forces were directly increased when the impact speed were higher as shown in Figure 8.

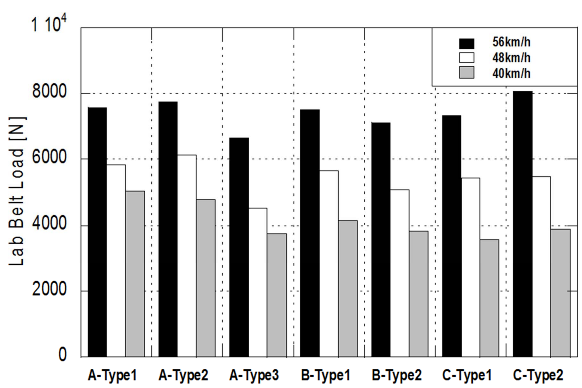

Figure 8. The lap belt forces in different speeds

Although should belt forces were not proportionally increased by the higher impact speeds, the rib deflections were strongly influenced by the impact speeds. Since the shoulder belt force was measured from near the D-ring location, the actual thorax compression force was not uniformly distributed well. Also, this may cause by the coupling effects of the shoulder and lap belt forces.

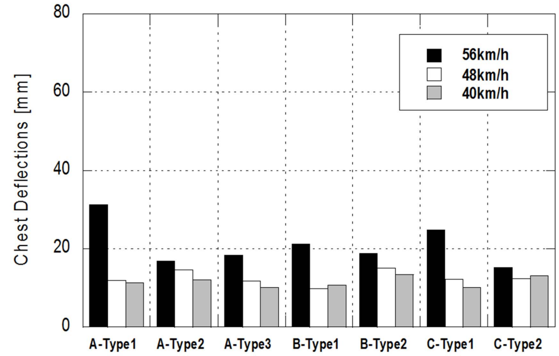

Figure 9. Chest deflections in different speeds

The chest deflections can be reduced when using the lower load limiter. Compared with 2.5kN load limiter and 1.5kN load limiter, the chest deflection can be reduced 24% of rib deflection as shown in Figure 10.

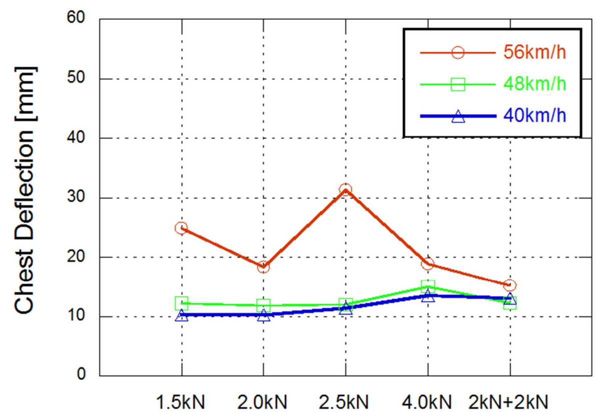

Figure 10. Chest deflections with different types of load limiters

ENHANCEMENT OF THE ELDERLY THORAX INJURY PROTECTIONS

Since 2009, the most of the KNCAP tested vehicles earned 5 star ratings in the full wrap 56 kph fontal impact test. Compared with previous year's (1999-2008) results as shown in Figure 11, the safety performances were dramatically improved. In 2009, the average of combined sever injury probability for the driver was 10.1% and 8.9% for the passenger.

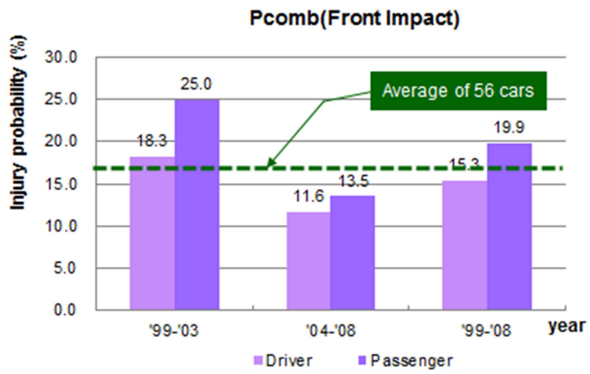

Figure 11. Improvement of vehicle safety in KNCAP Test

Currently, the most of vehicles earned the highest score from NCAP program around world except a few countries. But, elderly drivers and passengers have a disproportionately higher crash involvement rate and commonly sustain more severe injuries than the general population. As the population ages, there is a growing awareness of the need for vehicle safety to suit older occupants. It takes less energy to produce tissue damage in older adults, making this group more vulnerable to injury in a crash. Their skeletal structures are more easily damaged and the consequences of any assault are likely to be exaggerated by pre-existing health conditions.

Therefore, there is a need to improve the crashworthiness of vehicles to provide better protection for older occupants in the event of a crash. The level of personal mobility and independence afforded by the motorcar is fundamentally important for older people. The next generations of older drivers will bring a new set of challenges for road safety. The baby-boomer generation has grown up with the car, have higher licensing rates and travel longer distances by car than persons of their parents'' generation. As a consequence of the increased number of older drivers and passengers in the community and their greater reliance on cars for mobility, older occupant safety is likely to become a bigger issue in the years ahead.
The chest is clearly vulnerable as the major load bearing area for restraint systems as well as a major point of contact with the vehicle structure during a crash.

Currently, no motor vehicle safety standards in the world are designed to specifically address the needs of elderly persons. Currently, the Hybrid III 50%tile male dummy is only one dummy regulatory body accepted in the world except USA. To protect elderly occupants from the thoracic injury during the frontal crash events, the simply improvement of the chest deflection criteria only is not sufficient enough without the controlling the stiffer seat belt force level.

The load limiter in the 3-point belt is intended to limit the forces exerted by the belt and thus the values for the thoracic load. Already in the early 1970 load limiters were applied in serial production, at that time, of course, without airbag. Their benefit has been demonstrated by accident analyses. Today load limiters are mostly applied in combination with an airbag to achieve an optimum alignment of the restraint system.

From our researches and other previous researches, to protect elderly occupant from the thoracic injury, the load limiter should be in the range of 1.5 kN – 2.0 kN. In short term, if applying the modifier in the NCAP scoring system, this may lead the lowering seat belt force loadings as well as stimulating development of an adoptive restraint system as a universal design both beneficial for the standard size male occupant and the vulnerable occupants like elderly occupants and small size female occupants.

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