2019
22nd Presentation Session for Traffic Accident Investigations, Analysis, and Research

Accident characteristics of crossing collision accidents by elderly people

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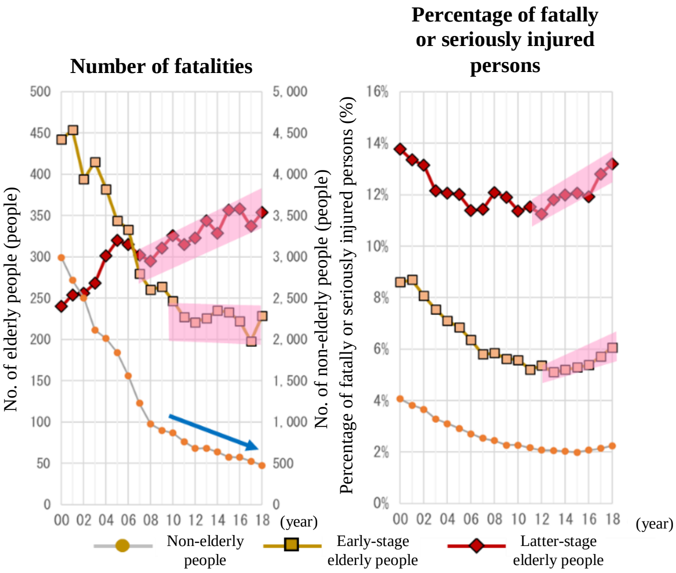
1. Current status of and trends in accidents as a whole

1-1. Trends in accidents as a whole

Record lows were recorded in 2018 for both the number of fatalities at 3,532 people and the number of casualties at 529,378 people. The government target for road traffic safety that was established in the Tenth Traffic Safety Basic Plan[1)] from 2016 called for achieving the safest road traffic seen anywhere in the world by reducing fatalities from traffic accidents to 2,500 people or less a year and the number of casualties from the same to 500,000 or less by the year 2020. Yet in response to this, the situation over achieving the target for fatalities has proven difficult, and further reductions must be made to both the number of fatally or seriously injured persons as well. Looking at a breakdown of this by circumstances reveals that approximately one-quarter of these cases involve people riding in a four-wheel vehicle, with the composition rate for this remaining largely unchanged compared with ten years ago. Dealing with passengers of four-wheel vehicles is currently regarded as an important component of this.



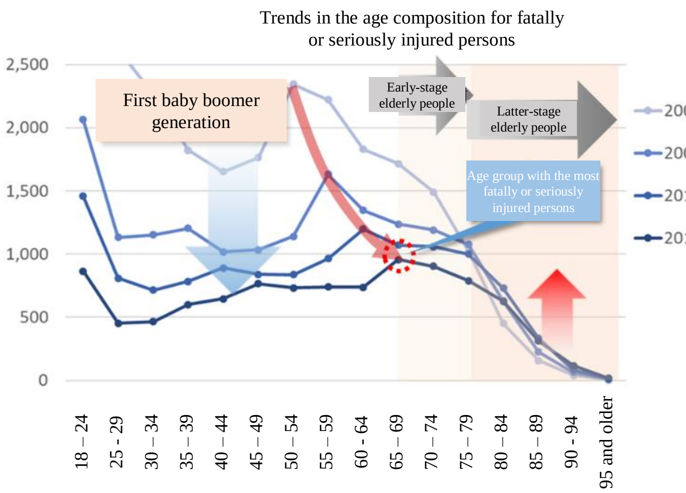
Fatalities, seriously injured persons, and casualties age 18 or older from 2000 - 2018; vehicle-vehicle and single vehicle accidents; riding or transporting cargo in medium / kei sized vehicles

Fig. 1. Trends in fatalities and the percentage of fatalities / serious injuries for passengers riding in four-wheel vehicles by age group

1-2. Trends in passengers of four-wheel vehicles by age

Trends in fatalities and the rate of fatalities / serious injuries for passengers riding in four-wheel vehicles (when riding in medium-sized or kei sized vehicles or using them to transport cargo) are shown in Fig. 1 for the respective groups of non-elderly people (ages 18 - 64), early-stage elderly people (ages 65 - 74), and latter-stage elderly people (ages 75 and over). While fatalities are in decline among non-elderly people, they are rising among latter-stage elderly people and holding steady among early-stage elderly people. What is more, the rate of fatalities / serious injuries, which indicates the share of persons suffering fatalities or serious injuries from among the number of casualties, has been increasing the further up in age a person is over these past several years.

A detailed breakdown of the age composition of fatally or seriously injured persons is shown in Fig. 2. While this has declined significantly for non-elderly people, the rate of decline among early-stage elderly people has been limited and it has even increased for latter-stage elderly people depending on their age range. Up until now, it had been the youngest age group that had suffered the most fatalities / serious injuries, but in 2018



Fatally or seriously injured persons age 18 or older in 2003, 2008, 2013, and 2018; vehicle-vehicle and single vehicle accidents; riding or transporting cargo in medium / kei sized vehicles

Fig. 2. Trends in the age composition of fatally or seriously injured persons who were passengers in four-wheel vehicle

people between the ages of 65 - 69 (corresponding to early-stage elderly people) suffered these the most. The fact that the first generation of baby boomers[2] (born between 1947 - 1949), which has formed the peak of the demographic groups, has reached old age is one factor pushing this further up the age range. As a result of such circumstances, the share of elderly people accounting for fatally or seriously injured persons among the passengers of four-wheel vehicles has doubled over the past 15 years to now account for 40% of the total, as shown in Fig. 3.

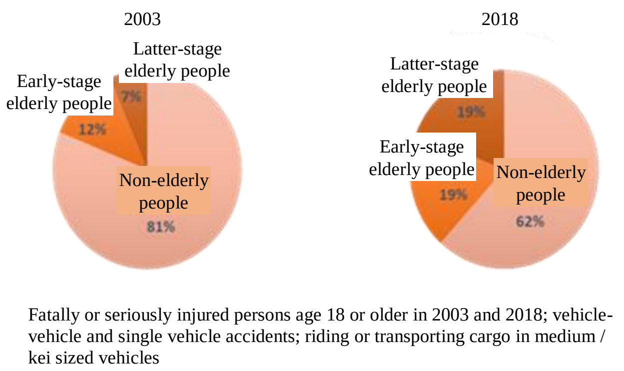


Fig. 3. Share of elderly people accounting for fatally or seriously injured persons among the passengers of four-wheel vehicles

From the above, the presumption is that the trends with aging will advance further in the future. Based on such circumstances, finding a way to reduce the number of fatally or seriously injured persons among elderly drivers, for which the share continues to rise, is an important challenge when it comes to reducing fatalities from traffic accidents.

2. Problems for elderly drivers in traffic accidents

2-1. Problems caused by aging

There are generally two types of problems thought to occur with elderly drivers. Fig. 4 shows the process from the driving behavior leading up to an accident to how the vehicle functions during an accident and the injuries suffered by the passengers of the vehicle. When it comes to driving behavior, drivers employ a series of functions that include cognition, judgment, and steering in order to attempt to avoid accidents. However, since driving ability deteriorates as a result of the declining mental and physical functions that accompany aging,[3)-5)] the risk of accidents increases. Moreover, in cases where the driver was unable to avoid a collision that resulted in an accident, depending on the vehicle there may be functions that come into play to mitigate the damage, or absorb the impact and protect the passengers when a collision does occur. However, these serve to pass along a shock to the human body as a result. Since the body's resilience declines as one ages, such cases present an increased risk of an injury occurring.

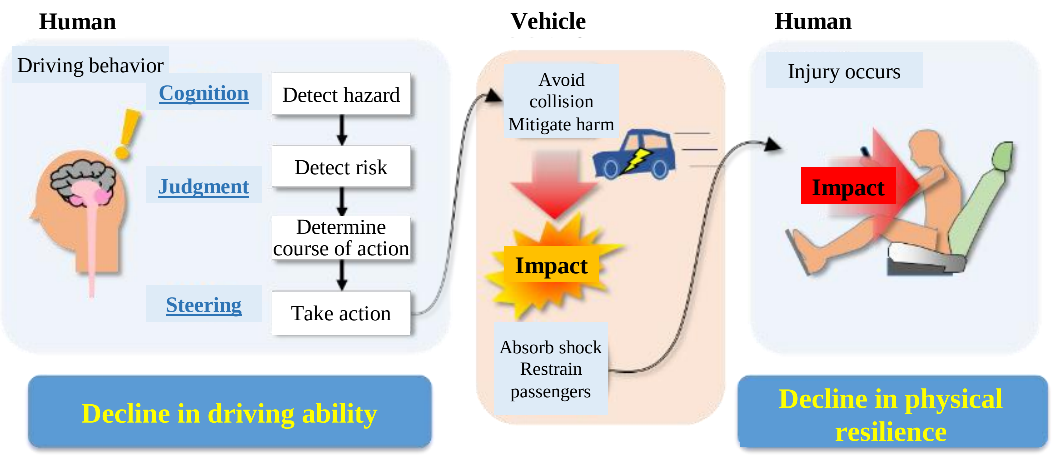
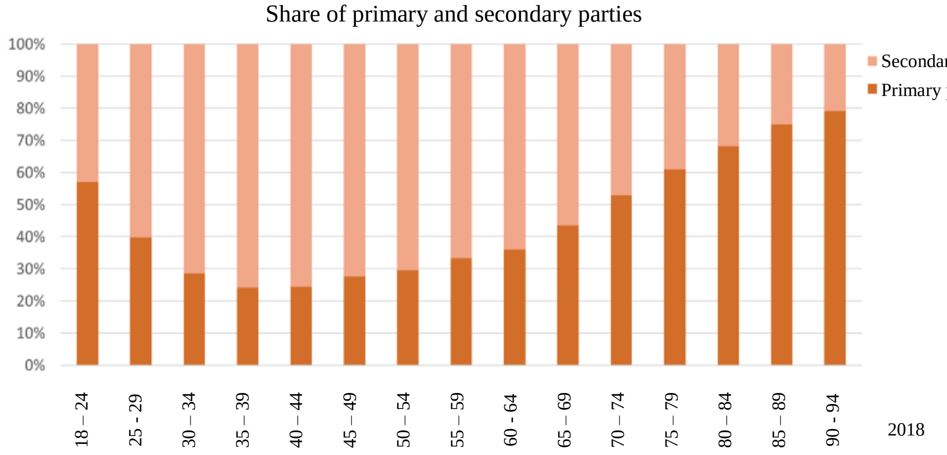


Fig. 4. Causes of accidents and their outcomes

2-2. Decline in driving ability

Fig. 5 shows the ratio of primary parties and secondary parties to accidents for each age range in five-year increments when it comes to the passengers of four-wheel vehicles in vehicle-vehicle and single vehicle accidents. The primary party is the side that served to cause the accident, and so presumably there is a higher likelihood that their driving behavior was more problematic compared with that of the secondary party. Since the share of primary parties rises the higher up in age you go, this could potentially indicate the manifestation of a decline in driving ability accompanying aging.



Fatally or seriously injured persons among the primary and secondary parties age 18 or older in 2018; vehicle-vehicle and single vehicle accidents; riding or transporting cargo in medium / kei sized vehicles

Fig. 5. Composition rate of primary parties to secondary parties by age group

2-3. Decline in physical resilience

When it comes to the decline in physical resilience, it is commonly known that the strength of one's bones declines as one ages.[6)] Fig. 6 is a diagram known as an "Injury risk curve,"[7)] which expresses the risk of a person suffering a chest injury and the connection with indicators of injury. Chest deflection, which indicates the risk of fracturing one's ribs, is one indicator of injury to the chest area. This is indicated along the horizontal axis. The risk of injury occurring is indicted by the AIS scale, which is a simple indicator of injury. The risk of an injury at or above the level of an AIS3, which indicates a fracture of three or more ribs and which corresponds to a serious injury, is shown along the vertical axis. The fact that a 35-year old has a 15% probability of suffering from such an injury when there is a chest deflection of 42mm, whereas a 65-year old has a slightly less than four-fold probability of this at 50% with the same chest deflection, serves as confirmation of the greater risk faced by those in old age.

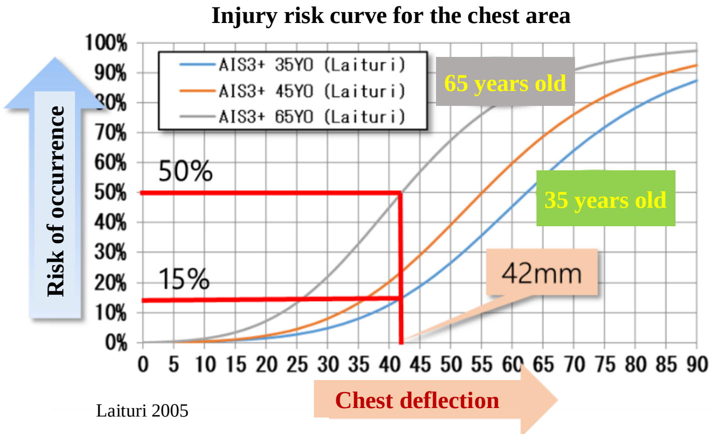


Fig. 6. Injury risk curve

This study analyzed the driving characteristics and quality of injuries of elderly drivers from two dimensions: the increased risk of accidents caused by a decline in one's driving ability due to aging, as well as the increased risk of injury caused by a decline in physical resilience.

3. Characteristics of Accidents Caused by Elderly Drivers

3-1. Characteristics of accidents

A breakdown of the types of accidents involving fatally or seriously injured persons caused by elderly drivers is shown in Fig. 7. Crossing collisions, head-on collisions, and single vehicle accidents with roadside structures account for 70% of fatally or seriously injured persons. In particular, crossing collisions and single-vehicle accidents with roadside structure account for a large share of these compared with non-elderly people. Next, these three accident types will be analyzed in terms of the human factors leading to them and the degree of the impact sustained from the perspectives of driving ability and physical resilience.

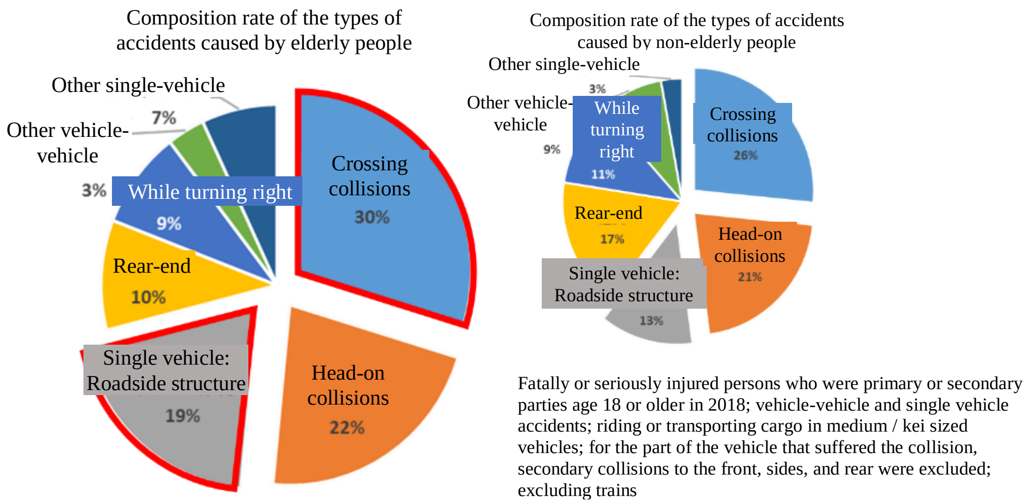


Fig. 7. Composition rate of the types of accidents caused by each age group

3-2. Human factors

A breakdown of the human factors behind these three accident types is shown in Fig. 8. A failure to confirm safety factors accounts for 75% of crossing collisions, with a large proportion of these being due to cognitive errors. A failure to pay attention to what is up ahead serves as the primary cause of head-on collisions, while driving operation error (operating error) is the primary cause for collisions with roadside structures. The decline in one's driving ability due to aging can be considered for each of these. With the failure to confirm safety factors in crossing collisions in particular, there is a vast range to cover and the risk of errors is potentially enormous.

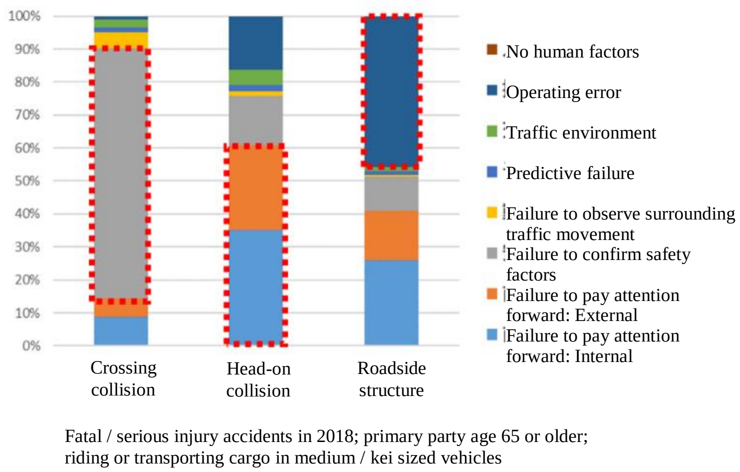
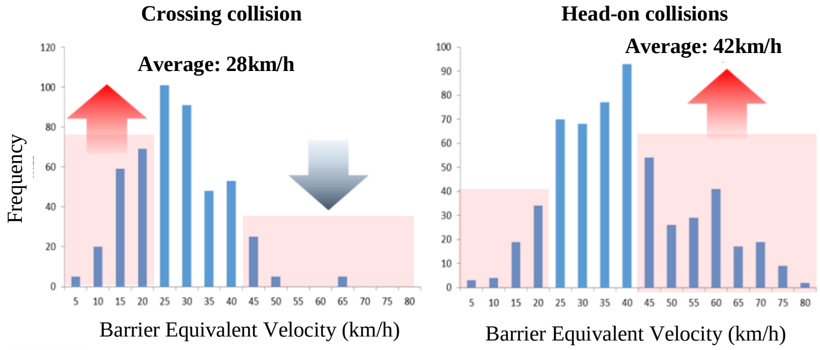


Fig. 8. Human factors behind accidents by elderly people

On the other hand, the recent advances in support technologies for errors by the vehicles themselves have been remarkable, with progress being made on their practical implementation as advanced safety technologies.[8] For example, it is conceivable that accidents like head-on collisions and collisions with roadside structures due to drivers deviating from their lanes could be reduced through advanced safety technologies such as lane deviation prevention devices. However, as was mentioned above, with cognition when it comes to crossing collisions there is a vast range to cover and a wide range of phenomena. Therefore, it will presumably take time in order to reduce the number of crossing collision accidents via this, and this will require priority initiatives in the future.

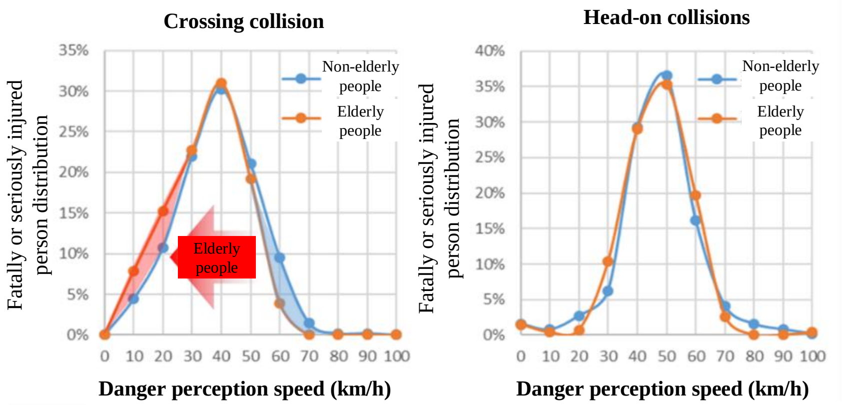
3-3. Degree of impact

The Barrier Equivalent Velocity is used as an indicator for the degree of impact. The Barrier Equivalent Velocity indicates the speed that would produce the same amount of deformation as an actual accident when there is a collision with a fixed wall. Using this, the degree of impact can be compared for two different types of collision phenomena by excluding factors such as the weight and speed of the other party to the collision.



Micro data from 2006 - 2016; AIS1+; riding or transporting cargo in medium / kei sized vehicles; age 18 or older; in front of the vehicle suffered from the collision; crossing collisions: N=481, head-on collisions: N=579, collisions with roadside structures: N=379

Fig. 9 Comparison of the Barrier Equivalent Velocities



A danger perception speed of 20km/h refers to a speed range of over 10km/h up to 20km/h

Fatally or seriously injured persons who were primary or secondary parties age 18 or older in 2018; medium / kei sized vehicles; for the part of the vehicle that suffered the collision, secondary collisions to the front were excluded

Fig. 10. Danger perception speed distribution

The distribution for Barrier Equivalent Velocities from crossing collisions and head-on collisions when the region of the collision is the front of the vehicle as calculated from the micro data is shown in Fig. 9. With head-on collisions, the distribution of Barrier Equivalent Velocities is heavily tilted towards the high-speed range, with the average for all speeds coming to 42km/h. Conversely, with crossing collisions this is heavily tilted towards the low-speed range, with a low average for all speeds of 14km/h. In other words, due to the high degree of impact on elderly people, who have diminished physical resilience, from head-on collisions and collisions with roadside structures, these constitute harsh conditions for them. This is believed to be one of the reasons for their prevalence of fatally or seriously injured persons. What is more, when the distribution for the danger perception speeds is compared for crossing collisions and head-on collisions by age range, virtually no difference was observed by age range with head-on collisions, as indicated in Fig. 10. However, with crossing collisions elderly people were overly inclined to view relatively lower speed ranges as being dangerous compared with non-elderly people. To put this another way, despite the fact that crossing collisions constitute conditions with a low degree of impact for elderly people, they account for a large share of fatally or seriously injured persons. This could potentially be because the elderly often tend to sustain injuries from them due to their lower physical resilience.

From the results thus far, the thinking is that the crossing collision accidents that account for a large share of the fatally or seriously injured persons among elderly drivers are significantly affected by the decline in driving ability caused by aging. What is more, there is also the conceivable possibility that elderly drivers drive at lower speeds to compensate for their declining cognitive functions. On the other hand, compared with head-on collisions and collisions with roadside structures, which feature a high degree of impact, these presumably constitute conditions in which the effects of a decline in physical resilience are more readily apparent. Therefore, with crossing collisions it will be necessary to concretely specify the status of cognitive errors from the perspective of human factors, as well as the situation concerning what sorts of injuries occur at low degrees of impact from the perspective of the degree of impact. Following this, an analysis will be performed on the status of accidents caused by cognitive errors and the extent to which injuries occur during crossing collision accidents.

4. Accident Considerations and Thoughts on Dealing with Them

4-1. Driving behavior during crossing collision accidents

To begin with, the driving behavior from crossing collisions will be analyzed for both non-elderly people and elderly people. For this, the distribution of danger perception speeds was investigated for both primary and secondary parties and by whether or not signal control was involved. As the primary party is the side that served to cause the accident, there is the possibility that their driving behavior will differ from that of the secondary party, who unwittingly became involved in the accident. An image of the crossing collision accident conditions is shown in Fig. 11. It shows an accident between a primary party attempting to travel straight in an upward direction from the bottom of the road diagram and a secondary party crossing the intersection. The direction of the secondary party was analyzed by whether they were coming from the left or right.

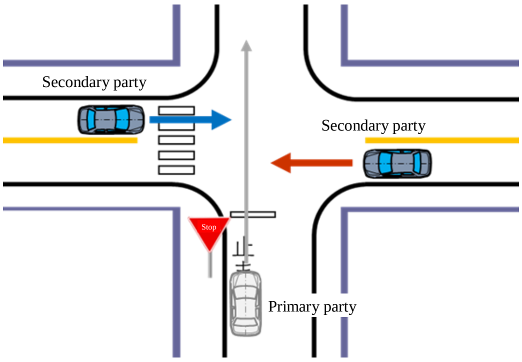
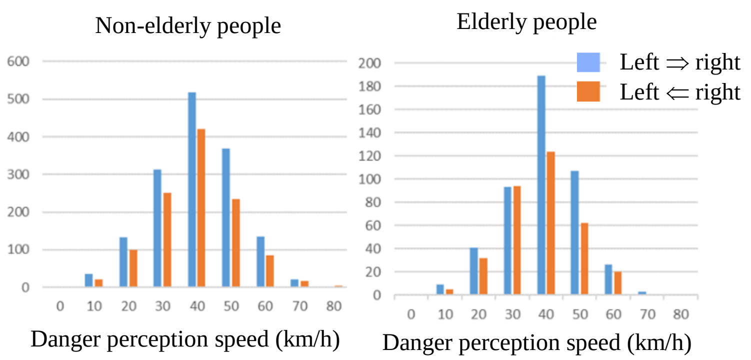


Fig. 11. Diagram of the conditions of a crossing collision accident (no signal control)

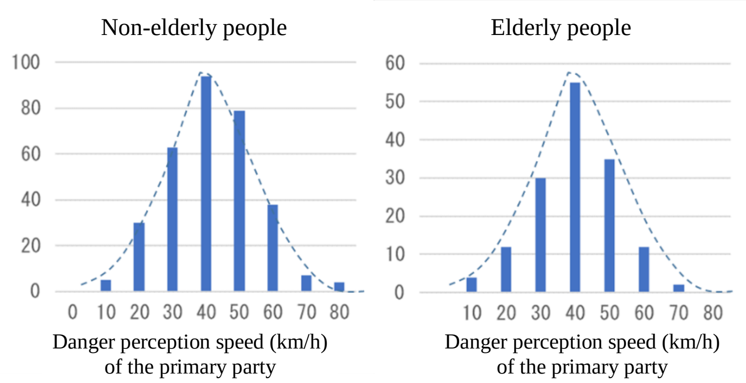
The distribution for the danger perception speeds of secondary parties when there is no signal control (70% of the tabulated conditions in question) is shown in Fig. 12. The blue indicates a secondary party heading from left to right, while orange shows them heading from right to left. The results indicate a mountain-shaped distribution centered primarily around a speed range of over 30km/h up to 40km/h (hereafter, this will be denoted by using 40km/h to represent the highest speed). No major differences were observed in the distribution trends based on age range or the vehicle's direction of motion. This is estimated to be because the secondary party did not envision that the primary party would encroach into the intersection, and was proceeding along with the flow of traffic.



Fatally or seriously injured persons who were secondary parties age 18 or older from 2009 - 2018; crossing collision with no signal control; medium / kei sized vehicles; part of the secondary party's vehicle that suffered from the collision was the front and the side in the direction of motion of the primary party; primary party driving a four-wheel vehicle or motorcycle

Fig. 12. Speed distribution for the secondary party when there is no signal control

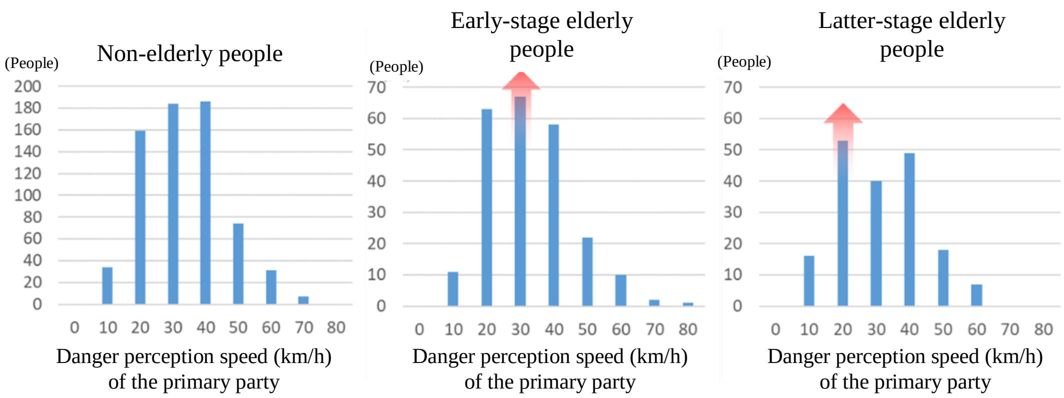
The distribution for the danger perception speeds of primary parties when there is signal control (27% of the tabulated conditions in question) is shown in Fig. 13. The assumption was made that the secondary party was coming from the left, as it would conceivably make it more complicated for the primary party to confirm the direction of the secondary party had they been coming from the right. The results were similar to those with the secondary parties listed above, in that it formed a mountain-shaped distribution that peaked at 40km/h, with the same tendency seen regardless of the age range. It is conjectured that the results were similar to the circumstances with the secondary party because they could proceed without becoming aware that a vehicle was approaching from either direction since signal control was in effect.



Fatally or seriously injured persons who were primary parties age 18 or older from 2009 - 2018; crossing collision with signal control; medium / kei sized vehicles; part of the primary party's vehicle that suffered from the collision was the front and the side in the direction of motion of the secondary party; secondary party driving a four-wheel vehicle or motorcycle

Fig. 13. Speed distribution for the primary party when there is signal control

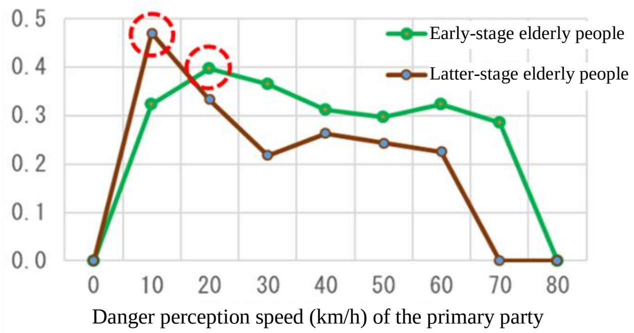
The distribution for the danger perception speeds of primary parties when there is no signal control (73% of the tabulated conditions in question) is shown in Fig. 14. The speed peak tended to be lower with them than with the secondary parties on the whole. This tendency was particularly pronounced with elderly people. The danger perception speeds of early-stage and latter-stage elderly people versus the share from non-elderly people are shown in Fig. 15. Latter-stage elderly people have a larger share of this in the medium to lower speed range (40km/h or less), with the tendency to enter intersections at lower speeds becoming more pronounced the older one gets. It is conceivably possible that this is because since it takes more time to make confirmation due to the decline in their cognitive function, they took compensatory actions such as reducing their speed to ensure ease of confirmation.



Fatally or seriously injured persons who were primary parties age 18 or older from 2009 - 2018; crossing collision with no signal control; medium / kei sized vehicles; secondary party driving a four-wheel vehicle or motorcycle

Fig. 14. Speed distribution for the primary party when there is no signal control

From the above, it was learned that primary parties where there is no signal control have the potential to be affected by a decrease in driving ability resulting from aging. Under such circumstances, it would potentially be possible to effectively reduce accidents by supporting the cognitive functions of drivers with respect to vehicles approaching from the left or right side. Consideration has also been given to autonomous vehicle detection for vehicles approaching from the left or right sides via radar, cameras, and other equipment installed on one's vehicle. A method of detecting other vehicles via communication between vehicle detection devices installed on other vehicles approaching from the side and on the road has also been taken into consideration via vehicle-to-vehicle and road-to-vehicle communication devices.[9)] The presumption is that these sorts of devices can effectively reduce accidents by providing notification to the driver.



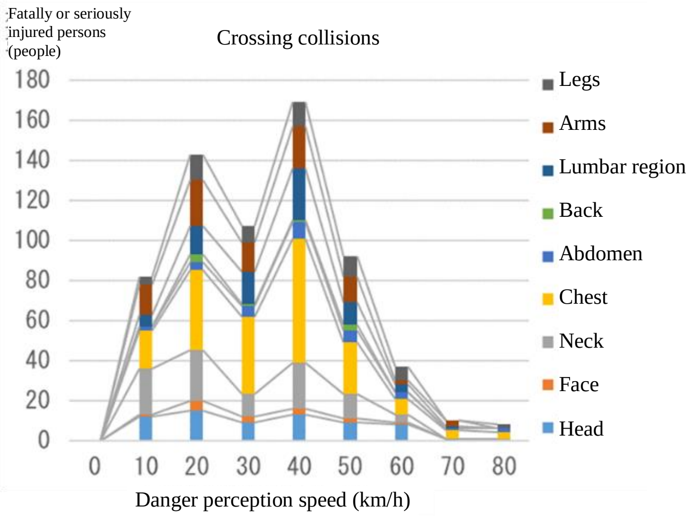
Fatally or seriously injured persons who were primary parties age 18 or older from 2009 - 2018; crossing collision with no signal control; medium / kei sized vehicles; fatally or seriously injured persons who were primary parties age 18 or older from 2009 - 2018; crossing collision with no signal control; medium / kei sized vehicles

Fig. 15. Speed distribution for the primary party when there is no signal control (ratio versus non-elderly people)

4-2. Status of injuries occurring from crossing collision accidents

The share of major body parts that sustained injuries on non-elderly people during crossing collisions for each danger perception speed are shown in Fig. 16. The analysis was performed when the part of the vehicle that suffered from the collision was the front. The most frequently injured part of the body was the chest area, exhibiting a distribution that peaked around 40km/h on the whole.

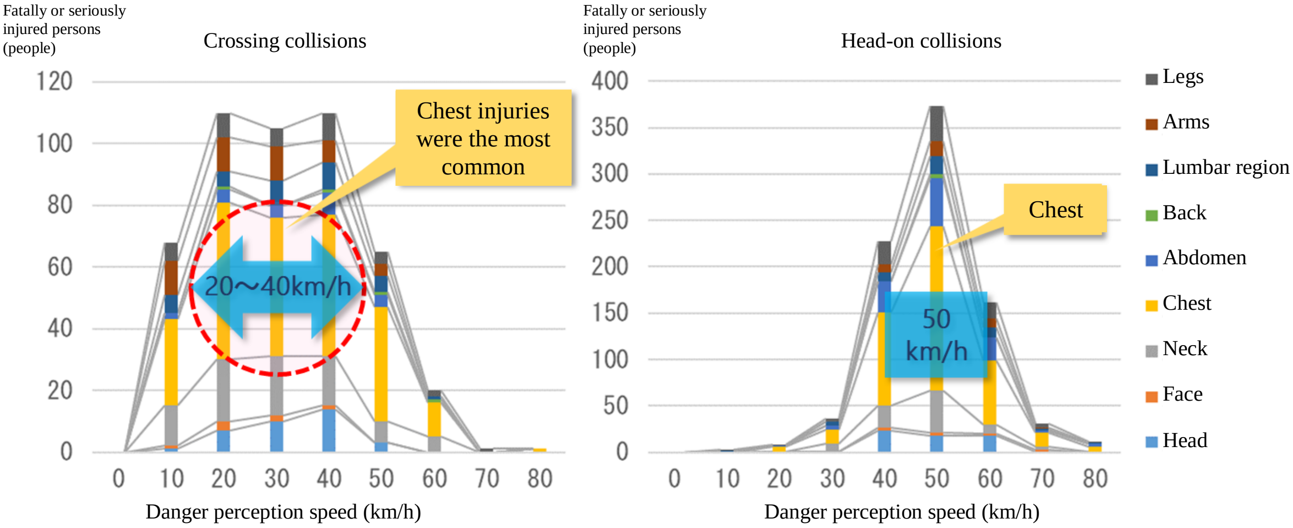
Conversely, the distribution for crossing collisions and head-on collisions for elderly people is shown in Fig. 17. The distribution for crossing collisions is arranged in a trapezoidal shape over the low-speed range of 20 - 40km/h. Just the same as with non-elderly people, the part of the body they injured the most frequently was the chest area, which accounted for roughly 50% of the injuries from crossing collisions across all speed ranges. In addition, for head-on collisions this is distributed in a mountain-like shape peaking at 50km/h. A similar trend was seen here with non-elderly people as well, with no difference observed. Compared to with head-on collisions, with crossing collisions a roughly equivalent composition and number of injuries was seen in both the 20km/h and under speed range as with the 40km/h one, with the decline in resilience due to aging thought to be one



Fatally or seriously injured persons who were primary parties age 18 or older from 2013 - 2018; medium / kei sized vehicles; part of the vehicle that suffered the collision was the front

Fig. 16. Share of major body parts that sustained injuries on non-elderly people during crossing collisions for each speed

factor behind this.



Fatally or seriously injured persons who were primary parties age 18 or older from 2013 - 2018; medium / kei sized vehicles; part of the vehicle that suffered the collision was the front

Fig. 17. Share of major body parts that sustained injuries on elderly people during crossing collisions and head-on collisions for each speed

The results of an analysis from micro data from 2006 - 2016 on the parts that caused the damage with injuries to the chest area are shown in Fig. 18. When the level of injury was deemed to be AIS2+, which is the level of a rib fracture, then in most cases the injuries in crossing collisions and head-on collisions (limited to collisions involving the front of the vehicle in both cases) were due to the seat belt, with these at 74% and 39%, respectively. A trait that seat belts must have is that they must involve minimal damage.

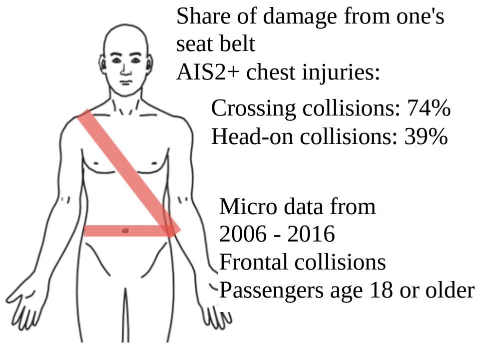


Fig. 18. Part that caused the damage with injuries to the chest area

4-3. Protective features for passengers for crossing collision accidents

The working condition of the restrain systems equipped on a vehicle should be confirmed in order to cut down on injuries. Table 1 shows the operating rate for airbags in seats equipped with them for each danger perception speed across the top, as well as the number of fatally or seriously injured persons across the bottom (for collisions where the front of the vehicle was the section that collided). Normally, automobile manufacturers design airbags and other restraint systems to operate in collisions against a fixed barrier at speeds of 20 - 30km/h or greater.[10)]
With head-on collisions, the deployment rate within the speed range of 30km/h is 72%. With collisions with roadside structures, their operating rate is largely identical at 76%. Here, if we were to assume that 72% is the manufacturers' intended operating deployment rate, then a similar operating rate would be achieved in crossing collision accidents at a speed of 60km/h.

Table 1. Air bag deployment rate for fatal or serious injury accidents and fatally or seriously injured persons

	Danger perception speed (km/h)	0	10	20	30	40	50	60	70	80	90	
Restraint device operating rate (frontal collision air bags, seat belt pretensioners)	Head-on collisions	57%	86%	69%	72%	84%	89%	93%	95%	93%	91%	
	Crossing collisions	-	29%	36%	43%	56%	67%	72%	71%	67%	100%	
	Collisions with roadside structures	-	39%	45%	67%	76%	80%	82%	87%	85%	66%	Coverage rate
Fatally or seriously injured persons 2013～2018	Head-on collisions	96	51	113	320	1,334	1,830	752	164	74	22	95%
	Crossing collisions	0	216	526	741	1,271	848	329	66	18	4	10%
	Collisions with roadside structures	0	46	108	290	740	692	366	113	96	29	82%

Fatally or seriously injured persons who were primary or secondary parties age 18 or older from 2013 - 2018; medium / kei sized vehicles; part of the vehicle that suffered the collision was the front with no secondary collision; wearing a seat belt; vehicle equipped with air bag system

At the same time, if the same intended operating range were indicated for the lower column, then roughly 95% of head-on collisions would be covered whereas only 10% of crossing collision accidents could be covered.

The above indicates that the only restraint system for crossing collisions in the medium to low-speed range are seat belts. With elderly people in particular, this could conceivably increase their risk of injury when coupled with their declining physical resilience. What is more, since pretensioners do not work at medium to low speeds, this could potentially lead to insecure restraint of the passenger due to delays in the initial restraint being applied. Having pretensioners go into operation during crossing collisions could be done in an effort to ensure secure restraint of the passenger during crossing collision accidents, where there is a diverse array of collision conditions, and could possibly be expected to improve the protective features for passengers.

5. Summary

In terms of overall trends:

1 The number of fatalities among elderly passengers of four-wheel vehicles has not declined.

2 The situation must be handled from the dual dimensions of the decline in driving ability and the decline in physical resilience.

The characteristics of crossing collision accidents involving elderly people and future responses include:

3 Responding to crossing collision accidents that involve fatally or seriously injured persons is challenging.

- The decline in driving ability is thought to have an effect on primary parties where there is no signal control. When driving straight, the older one gets the greater the share of people who drive in the medium to low speed range.
- A large number of injuries occur within the medium to low-speed range.

Injuries to the chest area in particular account for half of the total, with much of this due to seat belt injuries.

4 The situation must be handled from the dual dimensions of the decline in driving ability and the decline in physical resilience.

- Notification functions / cognitive support from vehicle-to-vehicle communication, etc.
- Improving the operating rate of restraint systems will improve the early restriction of passengers.

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