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

Seat belt issues for reducing fatalities and serious injuries of child and elderly passengers

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1. Introduction

The traffic accidents that occurred within Japan in 2018 resulted in 529,378 casualties and 3,532 fatalities. In its Tenth Traffic Safety Basic Plan, the government set the targets of reducing the number of casualties to 500,000 people or less and the number of fatalities to 2,500 people or less by the year 2020, and it has been promoting a variety of measures to achieve this. As part of this, pedestrians, children, and elderly people, who are referred to as vulnerable road users, suffer a greater share of damage, and priority initiatives must be taken for them.

Fig. 1 shows the trend in the number of fatally or seriously injured persons per a population of 100,000 people[1)] by age group for passengers in the passenger and back seats of the primary and secondary party vehicles for kei, small, and medium sized (passenger) vehicles from the Integrated Database of Traffic Accidents. The number of said fatally or seriously injured persons has continued to decline across all age groups, which is believed to be a manifestation of the effects of various safety measures.

However, when you view a comparison for each age group, you see that the number of fatally or seriously injured persons among children between the ages of 6 - 12 and among the elderly age 65 and older has shown less of a decline compared with the cohort of non-elderly people between the ages of 20 - 64. This suggests that the measures have been slow in reaching them.

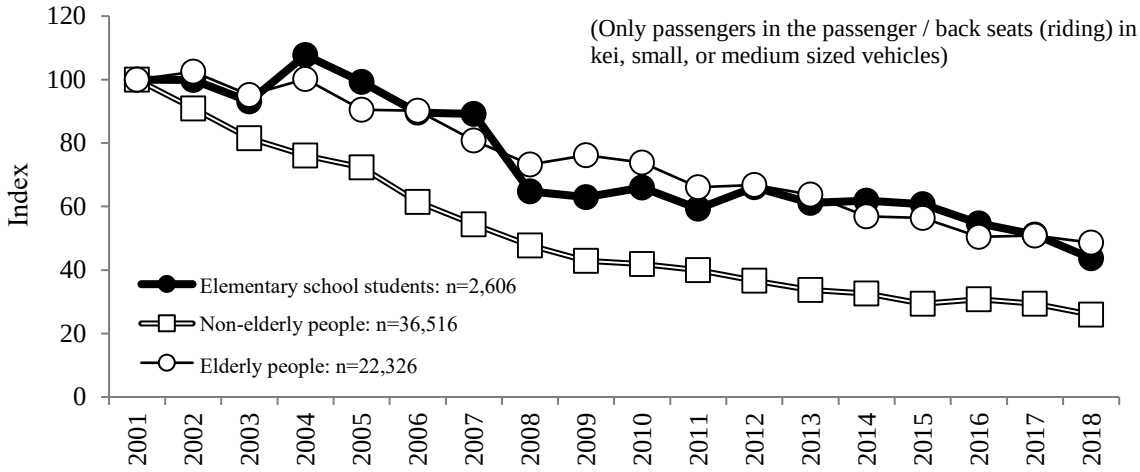


Fig. 1. Trends in the number of fatally or seriously injured persons per a population of 100,000 people among passengers by age group

(Number of fatally or seriously injured persons per a population of 100,000 people in 2001 taken to be 100)

Therefore, the actual status of accidents will be investigated in order to contribute to examining future measures for child passengers between the ages of 6 - 12 and elderly passengers at or above age 65. Since the usage or non-usage of seat belts is profoundly tied to whether or not injuries are sustained during an accident and the severity of said injuries, in subsequent sections the analysis will be performed by dividing passengers into those who were wearing and those not wearing their seat belt. The focus of the analysis was placed on fatal and serious injury accidents over a recent ten-year period from 2009 - 2018. Furthermore, since the majority of children between the ages of 6 - 12 are elementary school students, passengers between said ages are referred to below as "elementary school students" while passengers age 65 and over are referred to as "elderly people." They were compared with non-elderly people between the ages of 20 - 64 to examine their respective accident characteristics and challenges.

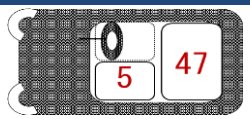
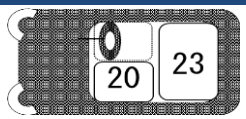
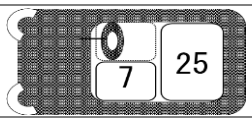
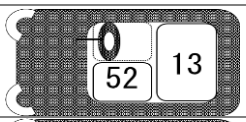
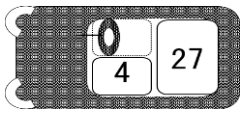
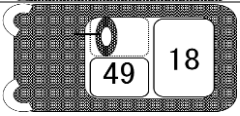
2. Issues from and an analysis of the non-use of seatbelts

Table 1 shows seat belt usage / non-usage rates for the actual conditions of seat belt use by fatally or seriously injured persons between the years 2009 - 2018. The definitions for this are provided below. This is a breakdown of

the fatal and serious injury accidents, and will vary from the actual usage rate across the market as a whole, including both accidents involving property damage and accident-free driving.

Usage rate = Number of fatally or seriously injured persons who were wearing their seat's seat belt ÷ Total number of fatally or seriously injured persons in the passenger and back seats × 100
Non-usage rate = Number of fatally or seriously injured persons who were not wearing their seat's seat belt ÷ Total number of fatally or seriously injured persons in the passenger and back seats × 100

Table 1. Seat belt non-usage rate for passengers in kei, small, and medium sized (passenger) vehicles when an accident occurred: 2009 – 2018

	Seat belts (total for 2009 - 2018)			
	Non-usage rate (%)	Usage rate (%)	Unknown (%)	Total (%)
Elementary school students			5	100
Non-elderly people			3	100
Elderly people			2	100

Number of fatally or seriously injured persons (usage, non-usage, unknown) between 2009 - 2018. Elderly people: n=11,447; Non-elderly people: n=12,961; Elementary school students: n=1,100.

Based on Table 1, we can see that the non-usage rate for elementary school students was 5% in the passenger seat and 47% in the back seat for a combined total that is over 50%. When elementary school students ride in a vehicle, they often have the opportunity to sit in the back seat, and they still have little awareness of wearing their seat belt in the back seat, which is a tendency common to all passengers as a whole. It is conceivably as a result of these factors that the share of elementary school students who do not wear their seat belt while riding in the back seat is higher compared with those of the other age groups at 47%. This non-usage rate of seat belts is thought to be a major contributing factor behind the delay seen in the decline in the number of fatally or seriously injured persons among elementary school students.

3. Issues in wearing one's seat belt

3-1. Parts of the body where elementary school students sustained injuries

Fig. 2 shows the composition ratio (%) for the parts of the body where fatally or seriously injured persons sustained injuries when they were wearing / not wearing their seat belt.
Fig. 2 reveals that the share of elementary school students who sustained injuries to their head and face was higher than that of the other age groups. It is said that children have a greater tendency to tip their upper body forward during collisions due to the large size of their head as a share of their total body size, as well as their high center of gravity.[2)] As such, the assumption is that their head and face frequently come into contact with the interior of the vehicle, causing them to sustain injuries. What is more, with all of the age groups switching from not wearing to wearing one's seat belt lessens the share of injuries sustained to the head and face, with the results of wearing this serving to reduce contact to the head and face.

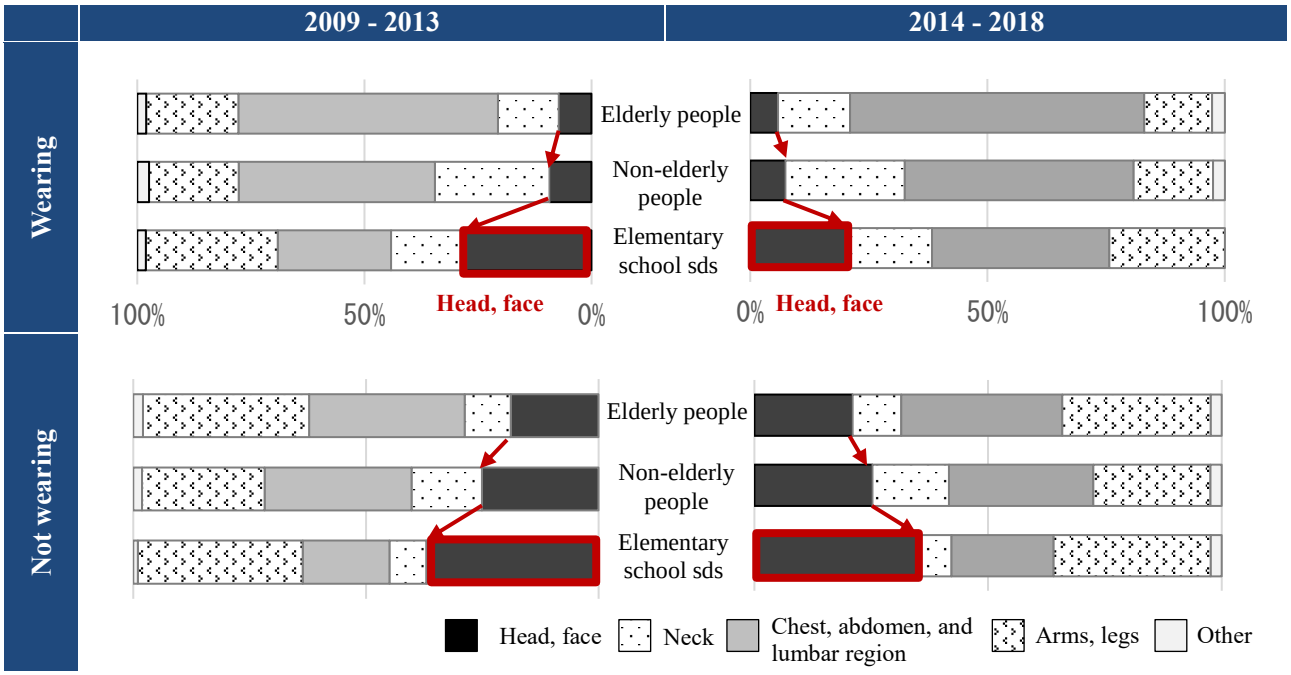


Fig. 2. Composition rate (%) for parts of the body where fatally or seriously injured persons sustained injuries: Challenges for elementary school students

Wearing seat belt Elderly people: n=7,632; Non-elderly people: n=8,453; Elementary school students: n=479
Not wearing seat belt Elderly people: n=3,547; Non-elderly people: n=4,141; Elementary school students: n=572

Conversely, insofar as switching from not wearing to wearing one's seat belt reduces the share of injuries sustained to the head and face for elderly and non-elderly people it has not led to a decrease for elementary school students, resulting in a widening gap across the age groups. This suggests that elementary school students face issues from their high center of gravity and other issues when it comes to fatalities and serious injuries when they wear their seat belt.

3-2. Parts of the body where elderly people sustain injuries

Similar to with Fig. 2, based on the composition ratio (%) for the parts of the body where fatally or seriously injured persons sustained injuries shown in Fig. 3 we can deduce challenges for elderly people.

Fig. 3 reveals that the largest share of injuries sustained by elderly people while wearing their seat belt occur to their chest, abdomen, and lumbar region, and that the number of said injuries increased from the 2009 - 2013 period to the 2014 - 2018 period. It has conventionally been claimed that elderly people are at increased risk of bone fractures due to a number of factors that accompany aging, such as diminished bone density, reduced flexibility from the calcification of costal cartilage around the ribs, and alteration of the angle of the rib cage.[3)] The results of Fig. 3 indicate that elderly people still face challenges in terms of sustaining injuries to their chest, abdomen, and lumbar region. In addition, while elderly people are at considerably high risk of injuries to this region, elementary school students and non-elderly people also face a high share of injuries sustained to their chest, abdomen, and lumbar region, with this trending upward as well. As such, it ought to be kept in mind that this is a challenge facing them just the same as for elderly people.

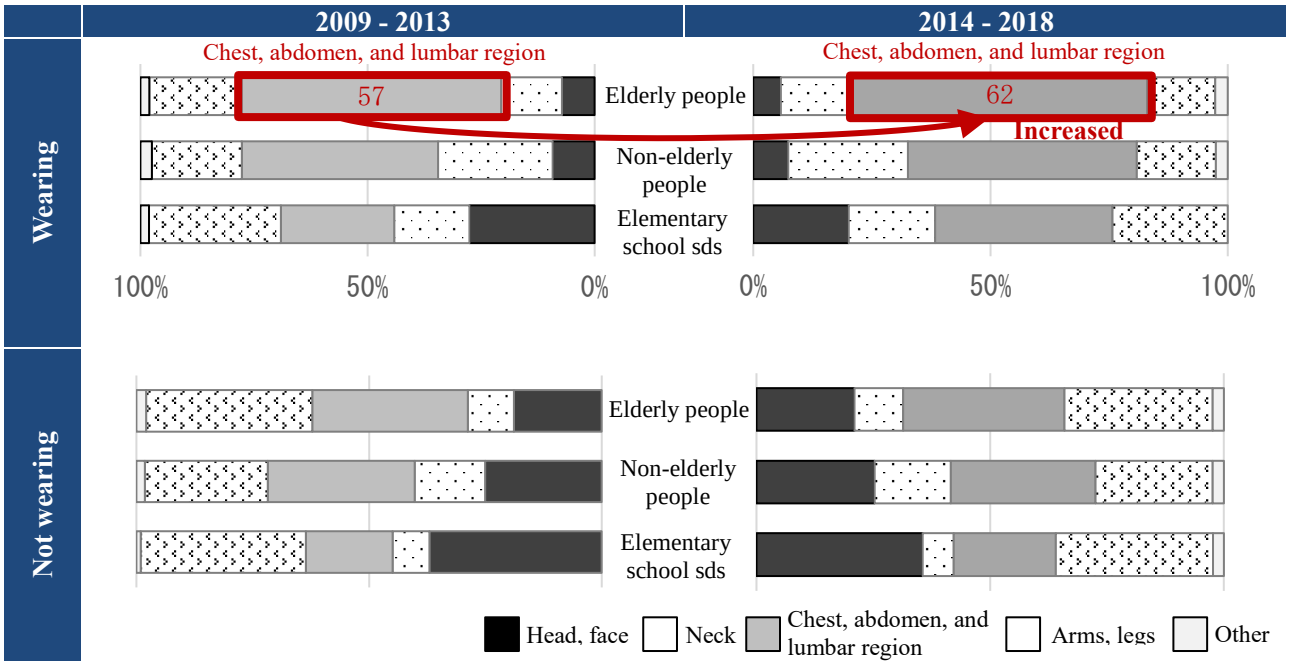


Fig. 3. Composition rate (%) for parts of the body where fatally or seriously injured persons sustained injuries: Challenges for elderly people

Wearing seat belt: Elderly people: n=7,632; Non-elderly people: n=8,453; Elementary school students: n=479
Not wearing seat belt: Elderly people: n=3,547; Non-elderly people: n=4,141; Elementary school students: n=572

4. Analysis of wearing one's seat belt: Elementary school students

4-1. Mechanism for injuries as seen from the connection between the parts of the body where elementary school students sustained injuries and their point of contact with the vehicle

Section 3-1 deduced the challenge that insofar as switching from not wearing to wearing one's seat belt reduces the share of injuries sustained to the head and face for elderly and non-elderly people, it has not led to a decrease for elementary school students, resulting in a widening gap across the age groups.

When elementary school students and adults are subjected to the same restraining force from their seat belt, the extent to which elementary school students--who have a body weight that is roughly half that of an adult and are shorter in stature as well--come out of their seat due to the impact from the accident is lessened. In addition, there is not thought to be any difference in the effect from their high center of gravity depending on whether or not they are wearing their seat belt. Yet despite this, the thinking is that the widening disparity in the share of injuries they sustain to their head and face is potentially a result of the seat belt, which is to say that they are not subject to the same restraining force as an adult.

This hypothesis will be considered based on the connection between the part of the body where injury was sustained and the point of contact with the vehicle. Fig. 4 shows the composition rates (%) for the part of the body that sustained injuries on fatally or seriously injured persons who were wearing their seat belt for both elementary school students and non-elderly people, and their point of contact with the vehicle. The size of the circles within the figure express the relative size of this composition rate.

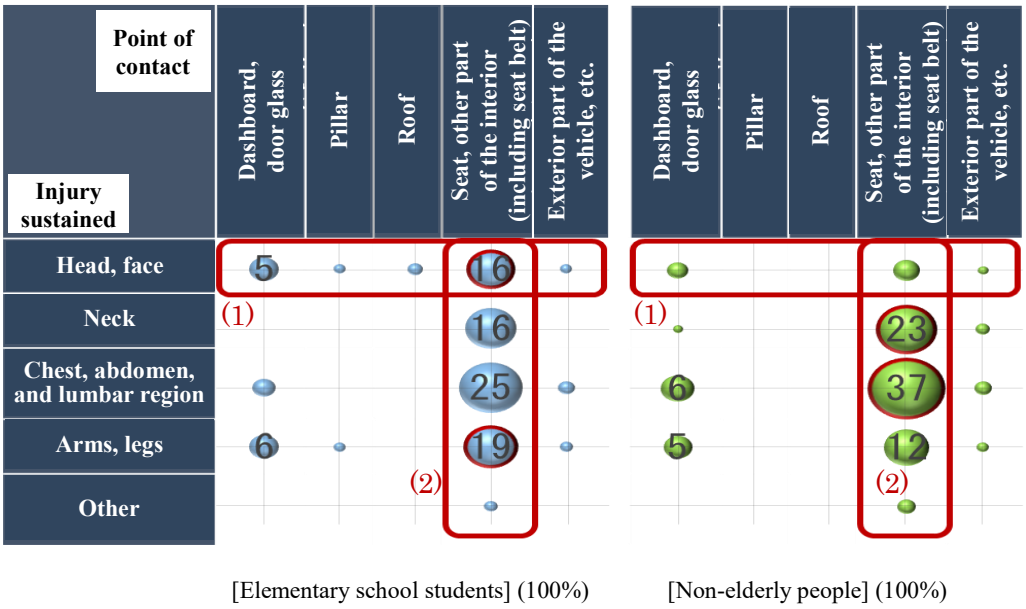


Fig. 4. Composition rate (%) of injuries sustained by fatally or seriously injured persons wearing their seat belt and their point of contact with the vehicle: 2009 - 2018

(Total number of fatally or seriously injured persons between 2009 - 2018. Fractions in the first decimal place were rounded up; 0 was left blank; Only a dot was entered for values between 1 - 5.)

Wearing seat belt Element school students: n=479, Non-elderly people: n=8,453

Fig. 4 (1) reveals that the heads and faces of elementary school students come into contact with a larger number of parts of the vehicle than do those of non-elderly people. Consequently, this is believed to be because even when they are wearing their seat belt, when they sustain the impact from an accident their head and face travel a greater distance than do those of non-elderly people. To put this another way, the extent to which their bodies come out of their seats tends to be greater than that of non-elderly people.

The points of contact with the vehicle such as the seat and other parts of the vehicle's interior (including the seat belt) from Fig. 4 (2) indicate that the parts of the bodies where non-elderly people sustain injuries are primarily concentrated around the neck and the center of the body around the chest, abdomen, and lumbar region. With this, there is the conceivable possibility that injuries are primarily sustained due to the force from the seat belt itself or often suffered from rebounding without hitting anything or whiplash from being restrained in the seat by the seat belt as a result of the restraining effect of the seat belt. Conversely, elementary school students frequently sustain injuries to their head and face as well as to their arms and legs, which are a slight distance from the center of their body. This can be taken to mean that they sustain injuries from contact with the seat and other parts within the vehicle, and that it is relatively rare for them to sustain injuries from the seat belt itself or from being restrained in their seat by the seat belt.

Based on the above, it is conceivably possible that the restraining force of the seat belt does not exert as much force on them as it does on adults, as mentioned above.

4-2. Extent of injuries sustained by elementary school students to their chest, abdomen, and lumbar region and the effects of wearing a seat belt

The extent of injuries sustained to the chest, abdomen, and lumbar region, which is in direct contact with the seat belt, will be compared for elementary school students and the other age groups to examine the causative factors producing the different results with the restraining force of the seat belt.

Fig. 5 shows the composition rate (%) for the extent of injuries sustained when the point of contact with the vehicle is the seat or other part of the vehicle's interior (including the seat belt) from 2009 - 2018.

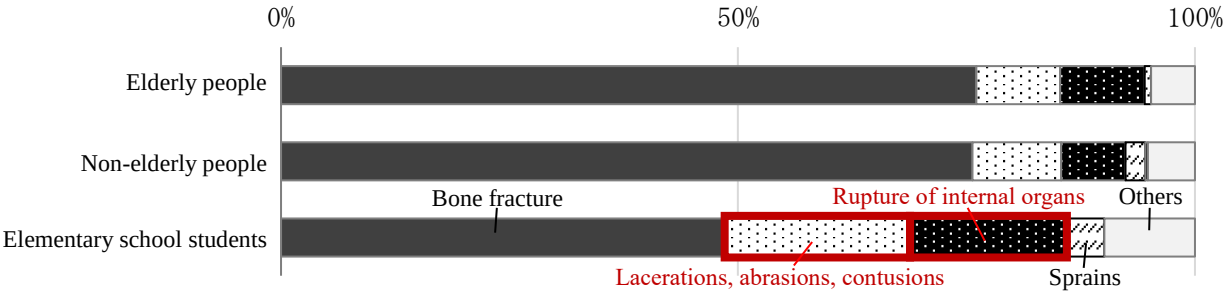


Fig. 5. Composition rate (%) for the extent of injuries sustained to the chest, abdomen, and lumbar region from the seat or other parts of the vehicle's interior (including the seat belt): 2009 - 2018

Wearing seat belt Elderly people: n=3,717; Non-elderly people: n=3,053; Element school students: n=121

Fig. 5 indicates that just like with elderly people and non-elderly people, with elementary school students bone fractures account for the greatest share of injuries. But aside from this, lacerations, abrasions, and contusions as well as ruptures of internal organs account for a roughly two-times greater share with elementary school students as opposed to with elderly people and non-elderly people, indicating that there is enormous variance in the extent of the injuries they sustain. From this, it can be surmised that there is potentially variance in where the belt is fastened, and that it oftentimes may not be fastened properly.

4-3. Manner in which elementary school students wear seat belts while riding in a vehicle

Generally speaking, the claim is made that seat belts are effective for people who are 140cm tall or taller. As indicated in Fig. 6, the results of a survey revealed that there are various different manners by which child passengers wear their seat belts while riding in a vehicle. These include cases where they wear them by displacing them due to a sense of discomfort with how the seat belt is supposed to sit due to their neck or the like, wearing them in a position with poor posture (such as slouched over, etc.), or removing the shoulder strap as a result of the driver maneuvering to avoid an obstacle.[4)-5)] There are thought to be numerous cases in which accidents occur under such circumstances and the victim sustains injuries when their head and face come into contact with parts within the vehicle without receiving the benefits of wearing a seat belt. This is believed to be one of the reasons behind the delayed reduction in the number of fatally or seriously injured persons who were wearing their seat belt.

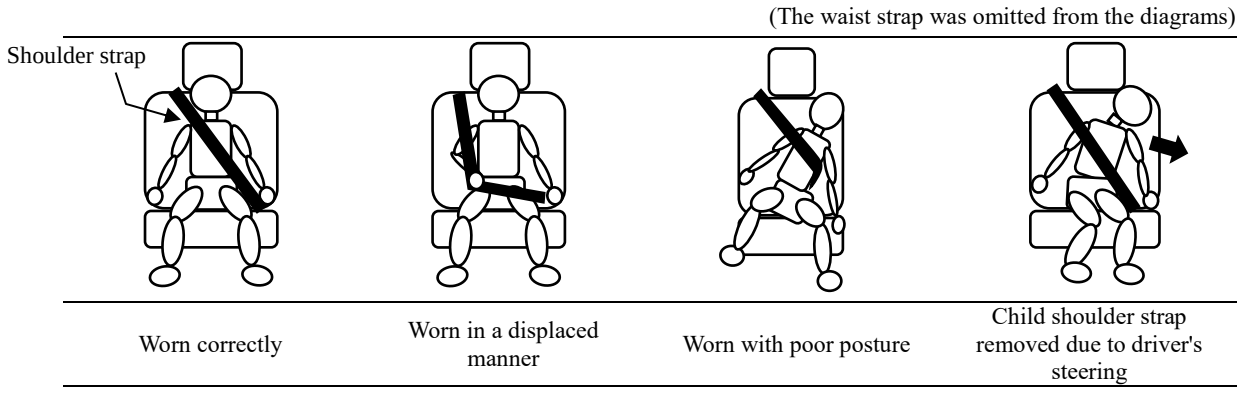


Fig. 6. Examples of the manner in which child passengers wear their shoulder strap

In order to obtain the benefits of wearing a seat belt, the seat belt must be properly fastened in place by eliminating any discomfort from the seat belt and maintaining the proper posture. This is to be done by means of adjusting the height of the shoulder strap, or by using a booster seat for children [6)-7)], which have been proven effective at reducing the risk of serious injuries in analyses of accidents in the US market.

5. Analysis of wearing one's seat belt: Elderly people

5-1. Mechanism for injuries as seen from the connection between the parts of the body where elderly people sustained injuries and their point of contact with the vehicle, as well as the status of the injuries sustained

The large share of injuries sustained by elderly people to their chest, abdomen, and lumbar region was taken up as an issue in Section 3-2.

Just like with in Chapter 4, a broad view will be taken of the distribution for the composition ratio (%) for the combined parts of the bodies where injuries were sustained by fatally or seriously injured persons wearing their seat belts among elderly people and non-elderly people, as well as their points of contact with the vehicle, between the years 2009 - 2018 to consider the factors behind the issue focused on, as indicated in Fig. 7.

Fig. 7. Composition rate (%) of injuries sustained by fatally or seriously injured persons wearing their seat belt and their point of contact with the vehicle: 2009 - 2018

(Total number of fatally or seriously injured persons between 2009 - 2018. Fractions in the first decimal place were rounded up; 0 was left blank; Only a dot was entered for values between 1 - 5.)

Wearing seat belt Elderly people: n=7,632; Non-elderly people: n=8,453

Fig. 7 (1) reveals that for injuries sustained by elderly people, the point of contact with the vehicle is concentrated at the seat and other parts inside the vehicle (including the seat belt). It also revealed that of these, injuries sustained to the chest, abdomen, and lumbar region accounted for 50% of the total injuries.

Therefore, viewing the extent of injuries sustained by elderly people to their chest, abdomen, and lumbar region by the seat and other parts inside the vehicle (including the seat belt) shows that bone fractures accounted for more than 70% of these, as indicated in Fig. 8.

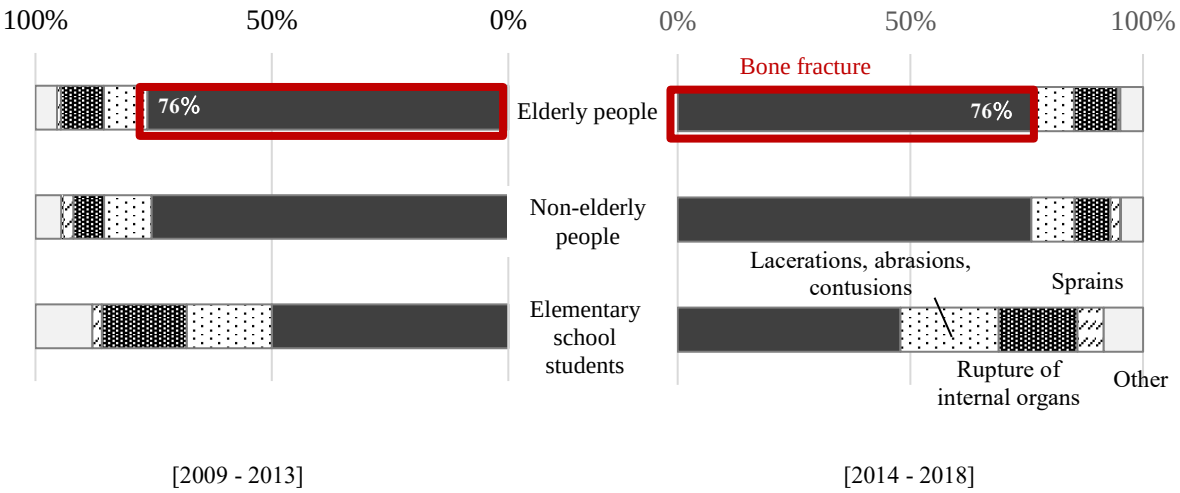


Fig. 8. Composition rate (%) for the extent of injuries sustained to the chest, abdomen, and lumbar region from the seat or other parts inside the vehicle (including the seat belt)

2009 - 2013 Elderly people: n=1,838; Non-elderly people: n=1,629; Elementary school students n=50
2014 - 2018 Elderly people: n=1,879; Non-elderly people: n=1,424; Elementary school students n=71

What is more, looking at the types of collisions that caused elderly people to sustain injuries to their chest, abdomen, and lumbar region due to the seat or other parts inside the vehicle (including the seat belt), reveals that frontal collisions accounted for 80% of these, as indicated in Fig. 9.

Consequently, it is conceivably possible that these injuries to the chest, abdomen, and lumbar region are sustained from the restraining force from the seat belt produced when the person's body is thrown forward, which is mainly seen when frontal collisions occur.

Based on the above, there is the conceivable possibility that the restraining force of the seat belt presents a problem in terms of injuring elderly people. Presumably, the restraining force of the seat belt will have to be modulated to be more suitable for elderly people in order to reduce the number of fatally or seriously injured persons.

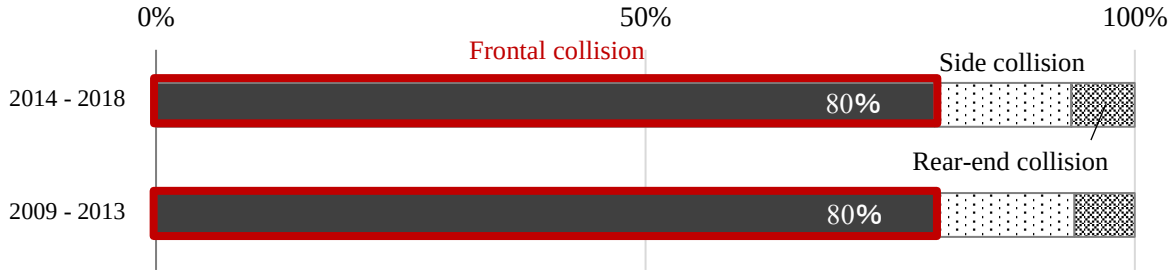


Fig. 9. Composition rate (%) of collision types where injuries were sustained to the chest, abdomen, and lumbar region

2009 – 2013 Frontal collisions: n=1,156; Side collisions: n=199; Rear-end collisions: n=89
2014 – 2018 Frontal collisions: n=1,116; Side collisions: n=196; Rear-end collisions: n=91
(excluding multivariate collisions)

5-2. Actual status of injuries sustained to the chest, abdomen, and lumbar region by elderly people as seen from a detailed breakdown by age

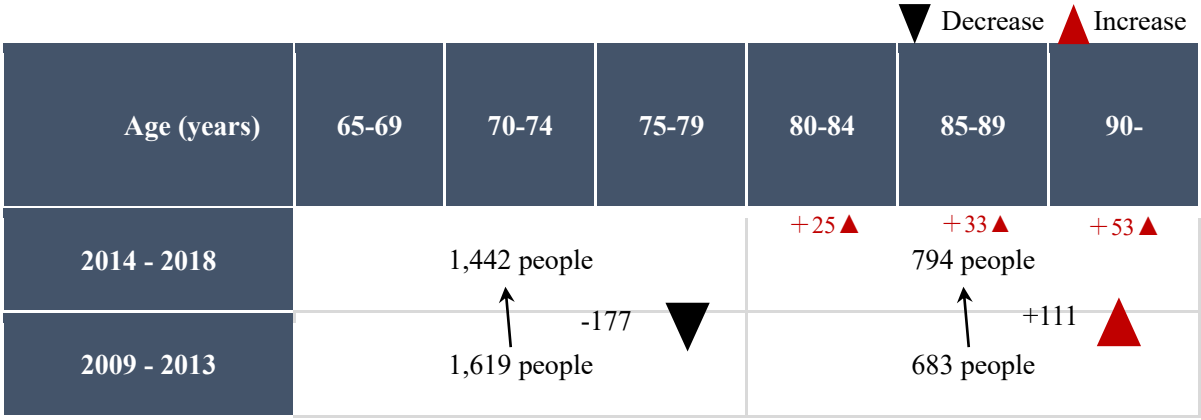
The fact that there is an upward trend in the share of injuries sustained to the chest, abdomen, and lumbar region is one of the issues that was taken up in Section 3-2. This section will analyze elderly people via a detailed breakdown of their ages in five-year intervals to examine the causes for this.

Fig. 10 shows the extent of the changes from the 2014 - 2018 period versus the 2009 - 2013 period regarding the

number of fatally or seriously injured persons who sustained injuries to their chest, abdomen, and lumbar region by a detailed breakdown of the ages of elderly people. The results of this indicate that the number of fatally or seriously injured persons at or over the age of 80 increased by 111 people. However, since this is conceivably due to the effects from the rise in the population of elderly people, the extent of the changes in the number of fatally or seriously injured persons for a population of 100,000 people at or above the age of 80 was ascertained as shown in Fig. 11. The results of this revealed that while this decreased for people between 80 - 84, it remained largely unchanged for those between 85 - 89 and increased for people age 90 and over.

Consequently, for people between the ages of 80 - 84, the increase in the number of fatally or seriously injured persons is thought to have been impacted by the rise in the population within this age group.

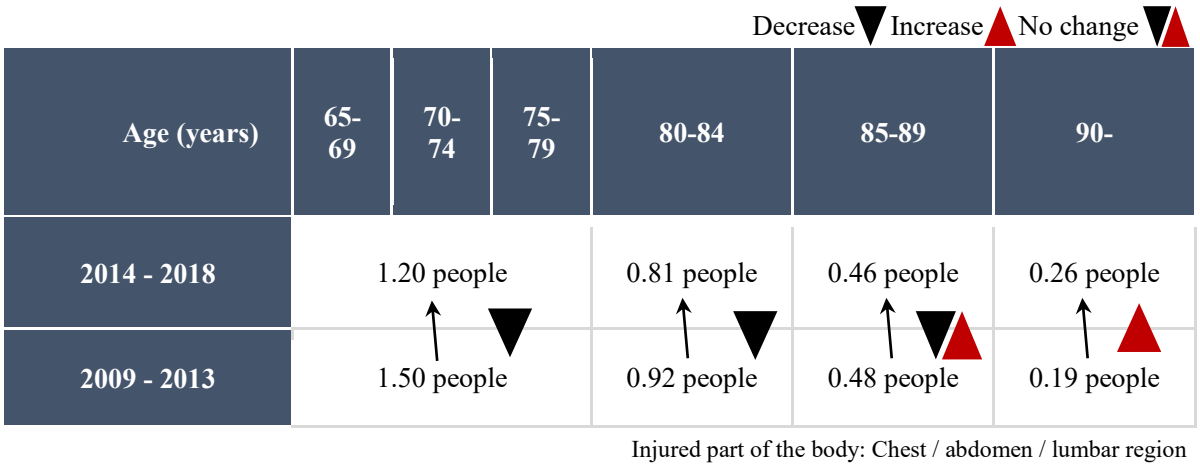
As for people between 85 - 89 years old, the number of fatally or seriously injured persons per 100,000 people has remained largely unchanged in contrast to the inherent assumption that it would decline due to factors like the drop in the number of accidents and improvements in the safety features of the vehicles themselves. For people age 90 and older, both the number of fatally or seriously injured persons and the number of said persons per 100,000 people have been increasing. For these reasons, conceivable factors behind the increase in the number of fatally or seriously injured persons among those age 85 and older include the fact that injuries sustained to the chest, abdomen, and lumbar region themselves have increased, with this not just related to the effects of the increase in the population. It is conceivably possible that the restraining force of the seat belt is a major factor behind the injuries sustained to the chest, abdomen, and lumbar region, with it within the realm of possibility that the problems from the restraining force of seat belts are exacerbated among those 85 and older. As the rise in the population of elderly people continues in the future, the number of fatally or seriously injured persons age 80 and older will continue to increase, just as it is doing now. This will serve as an inhibiting factor on any declines in the overall number of fatally or seriously injured persons.



Injured part of the body: Chest / abdomen / lumbar region

Fig. 10. Number of fatally or seriously injured persons (number of people)
by a detailed breakdown of ages of elderly people

Wearing seat belt 2009 – 2013 65 -79: n=1,619; 80 and older: n=683 2014 – 2018 65 -79: n=1,442; 80 and older: n=794



Injured part of the body: Chest / abdomen / lumbar region

Fig. 11. Number of fatally or seriously injured persons (number of people) per a population of 100,000 people by a detailed breakdown of the ages of elderly people

Number of fatally or seriously injured persons per 100,000 people
Age groups between 65 - 79 years old: Number of fatally or seriously injured persons for each age group ÷ Total population between 65 - 79 years old × 100,000
Age groups age 80 and older: Number of fatally or seriously injured persons ÷ Total population age 80 and older × 100,000

6. Conclusion

This study analyzed fatal and serious injury accidents among elementary school students (ages 6 - 12) and elderly people (age 65 and older) from the perspectives of "non-usage" and "usage" of one's seat belt. The following lessons were learned from the results of this.

Elementary school students

: Have a high share of seat belt non-usage.

: Even when they use them, there is still the possibility that they will sustain injuries from fastening their seat belt incorrectly.

Elderly people

: Continue to frequently sustain injuries to their chest, abdomen, and lumbar region.

: The number of fatally or seriously injured persons at or above the age of 80 has been rising. The number of fatally or seriously injured persons between the ages of 80 - 84 has been rising due to the effects from the increase in the population. For people age 85 and older, the problems with the restraining force of their seat belts is potentially being exacerbated.

: There are concerns that the rise in the population of elderly people in the future will lead to a further increase in the number of fatally or seriously injured persons.

Responses that will be necessary in the future will be considered below.

Elementary school students

: Learn how to correctly fasten their seat belt and soundly put this into practice (guardians).

: Consider measures such as activities to raise awareness of wearing one's seat belt, promote the dissemination of child seats for young children, and make their use mandatory.

Elderly people

: Improve the restraining force of seat belts.

: Further promote the dissemination of damage mitigation brakes as a way to reduce the speed at which collisions occur.

<Reference>

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