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The Detection of Pedestrians Crossing from the Oncoming Traffic Lane Side to Reduce Fatal Collisions Between Vehicles and Older Pedestrians

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Abstract

To inform the development of effective prevention strategies for reducing pedestrian fatalities in an ageing society, a retrospective analysis was conducted on fatal pedestrian–vehicle collisions in Japan. All pedestrian fatalities caused by motor vehicle collisions between 2013 and 2022 in Shiga Prefecture were reviewed. Among the 164 pedestrian fatalities (involving 92 males and 72 females), the most common scenario involved a pedestrian crossing the road (57.3%). In 61 cases (64.9%), pedestrians crossed from the oncoming traffic lane side to the vehicle's lane side (i.e., crossing from right to left from the driver's perspective, as vehicles drive on the left in Japan). In 33 cases (35.1%), pedestrians crossed from the vehicle's lane side to the oncoming traffic lane side. Among cases of pedestrians crossing from the vehicle's lane side, 54.5% were struck by the near side of the vehicle's front, whereas 39.7% of those crossing from the oncoming traffic lane side were hit by the far side of the vehicle's front ($p = 0.02$). Therefore, for both crossing directions, collisions frequently involved the front left of the vehicle. When pedestrians were struck by the front centre or front right of the vehicle, the collision speeds were higher when pedestrians crossed from the oncoming traffic lane side to the vehicle's lane side rather than crossing from the vehicle's lane side to the oncoming traffic lane side. A significant difference in collision speed was observed for impacts with the vehicle's front centre ($p = 0.048$). The findings suggest that increasing awareness that older pedestrians may cross roads from the oncoming traffic lane side may help drivers anticipate and avoid potential collisions.

Keywords: pedestrian; aged person; fatality; crossing; direction; safety

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1. Introduction

Road traffic deaths and injuries are a major global health and development challenge. In 2019, road accidents were the 12th leading cause of death worldwide [1]. Approximately half of all road fatalities involve pedestrians, cyclists, motorcyclists, or riders of other two- or three-wheeled vehicles. In addition, 80% of the world's roading fails to meet basic safety standards for pedestrians and cyclists, placing vulnerable road users at risk [1]. Therefore, promoting pedestrian safety is a priority worldwide. As most developed countries are rapidly transitioning to ageing societies, road traffic injuries among older people are becoming a major public health issue [2]. In Japan, the proportion of older people in the population is rapidly increasing, with people aged 65 years or above accounting for 29.1%

of the total population in 2023. One consequence of population ageing is an increase in the number of fatalities caused by road traffic injuries. In 2023, among 2678 road traffic fatalities occurring within 24 h of a collision in Japan, 54.7% of the victims were 65 years old or older [3]. Among the fatalities, pedestrians formed the largest group (36.3%), followed by motor vehicle passengers (31.3%), motorcyclists (19.0%), and bicyclists (12.9%). Moreover, people aged 65 years or older accounted for 70.6% of pedestrian fatalities. In response to this trend, the Japanese government emphasised the need for effective measures to address the challenges posed by an ageing population in the 11th Traffic Safety Basic Plan [4]. One of the four core principles of the plan highlights the need to further ensure the safety of vulnerable populations, such as older people. Therefore, the implementation of countermeasures designed to protect older pedestrians is an important means of reducing casualties of motor vehicle collisions (MVCs) in Japan.

The perceived risk of MVCs has been associated with mental well-being and physical functioning [5,6]. Neighbourhood safety, in particular, has been associated with cardiovascular health. A sex-stratified multilevel linear regression analysis revealed that living in neighbourhoods with a high perceived occurrence of MVCs is associated with an elevated risk of cardiovascular disease [7]. Therefore, preventing MVCs may not only reduce injury rates but could potentially also reduce cardiovascular disease and create a safer society.

The fatality risks of vulnerable road users in MVCs are affected by a range of factors, including road characteristics, type of collision, and environmental conditions [8]. Eluru et al. found that factors such as older age, higher speed limits, non-signalised intersections, and low-light conditions are associated with increased injury severity among vulnerable road users [9]. Abdel-Aty et al. found that the proximity to elementary schools, number of lanes, and speed limit are significant factors affecting the frequency of accidents involving vulnerable road users [10]. However, to the best of our knowledge, no previous studies have examined the detailed circumstances of pedestrian–motor vehicle collisions within a specific area in a super-ageing society. Improving pedestrian safety requires analysing the context of fatal pedestrian–vehicle collisions in a targeted area and implementing effective preventive measures.

The present study examined the situation of fatal pedestrian–vehicle collisions in an ageing society. Unlike previous studies, the current investigation focused on the collision characteristics of older pedestrians according to the direction of collision. Furthermore, we propose effective preventive measures for reducing pedestrian fatalities.

2. Materials and Methods

2.1. Sample

This study focused on pedestrian fatalities extracted from all fatal road traffic collisions that occurred in Shiga Prefecture, Japan, between 2013 and 2022. Shiga Prefecture is located in central Japan and has a population of approximately 1.4 million people. The authors reviewed all fatal road traffic collisions with the Traffic Department of Shiga Prefectural Police. Detailed collision information from police investigations was obtained from this review. Death was defined as a fatality occurring within 24 h of a collision. Moreover, comprehensive statistics on road traffic collisions in Japan were obtained from an all-inclusive database containing data provided by Japan's National Police Agency [11].

In each case, the following items were investigated:

- Basic information about the victim: Age and sex.
- The occurrence of the collision: Time and place.
- The width of the road: Less than 6 m, 6 m or more and less than 11 m, or 11 m or more.
- The situation of the collision: The type of vehicle (normal passenger vehicle, light passenger vehicle, or large vehicle [including trucks]), kinematics of the pedestrian

immediately before and after the collision, collision speed of the vehicle, and collision site of the vehicle (front centre, front right, or front left). The collision speed was determined by the police investigation; in addition to the driver's statement, videos from dashboard cameras, skid marks from the vehicle, and images from security cameras surrounding the scene were examined.

- The most severely injured body region: Head, neck, chest, abdomen, hip, or lower extremities, or cases involving severe bodily destruction.
- Information about the offending drivers: Age; use of alcohol or illicit drugs; history of dementia; visual impairment or hearing loss conflicting with the Road Traffic Law.

The study was performed with the approval of the Ethics Committee of Shiga University of Medical Science (R2024-068).

2.2. Statistical Analysis

Categorical variables are presented as a proportion or frequency. The normality of continuous values was examined with Shapiro–Wilk tests. The adequacy of this method was previously reported [12,13]. Continuous variables are given as mean ± standard deviation for values that follow a normal distribution and as the median and interquartile range (IQR) for values that are not normally distributed. A chi-square test was conducted to compare the prevalence between two groups. To identify differences in values between two groups, Student's *t*-test was conducted for values following a normal distribution, whereas a Mann–Whitney test was performed for values not following a normal distribution. A p value of ≤ 0.05 was considered to indicate statistical significance. The analyses were performed with SPSS Ver. 23.

3. Results

General Characteristics of Pedestrian Fatalities

From 2013 to 2022, there were 556 fatalities resulting from road traffic collisions in Shiga Prefecture. The distribution of road-user fatalities in this study closely mirrors national trends in Japan during the same timeframe (Figure 1). This suggests that the results for Shiga Prefecture are representative of the broader national context. During the 10-year period, 164 pedestrians (92 males and 72 females) were fatally injured in MVCs in Shiga Prefecture (Figure 2). The median age of the victims was 79 years (interquartile range: 59–81.3), and 65.9% of the victims were aged 65 or older.

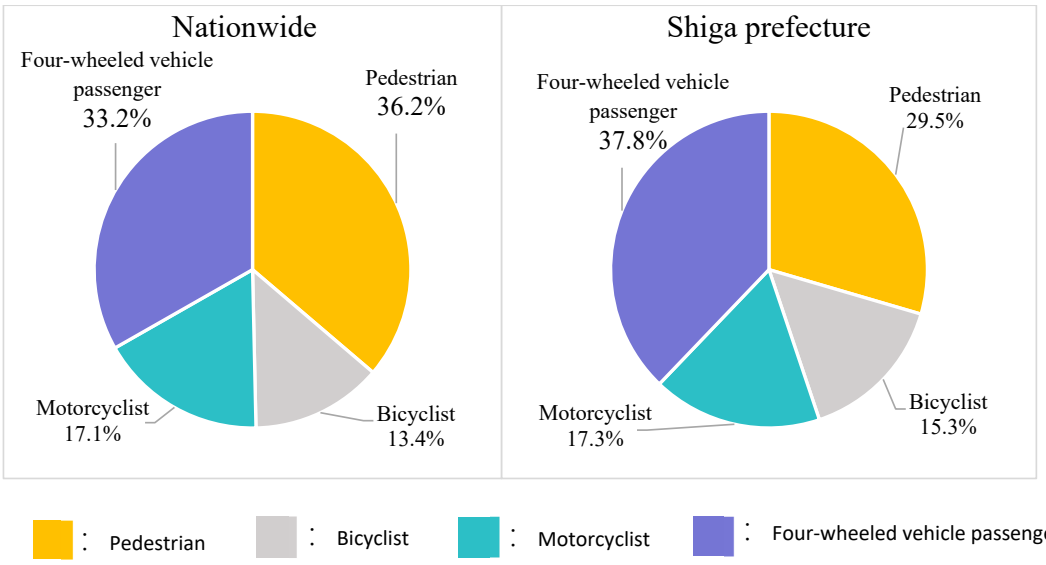


Figure 1. Road-user distributions of fatalities in Japan and Shiga Prefecture between 2013 and 2022.

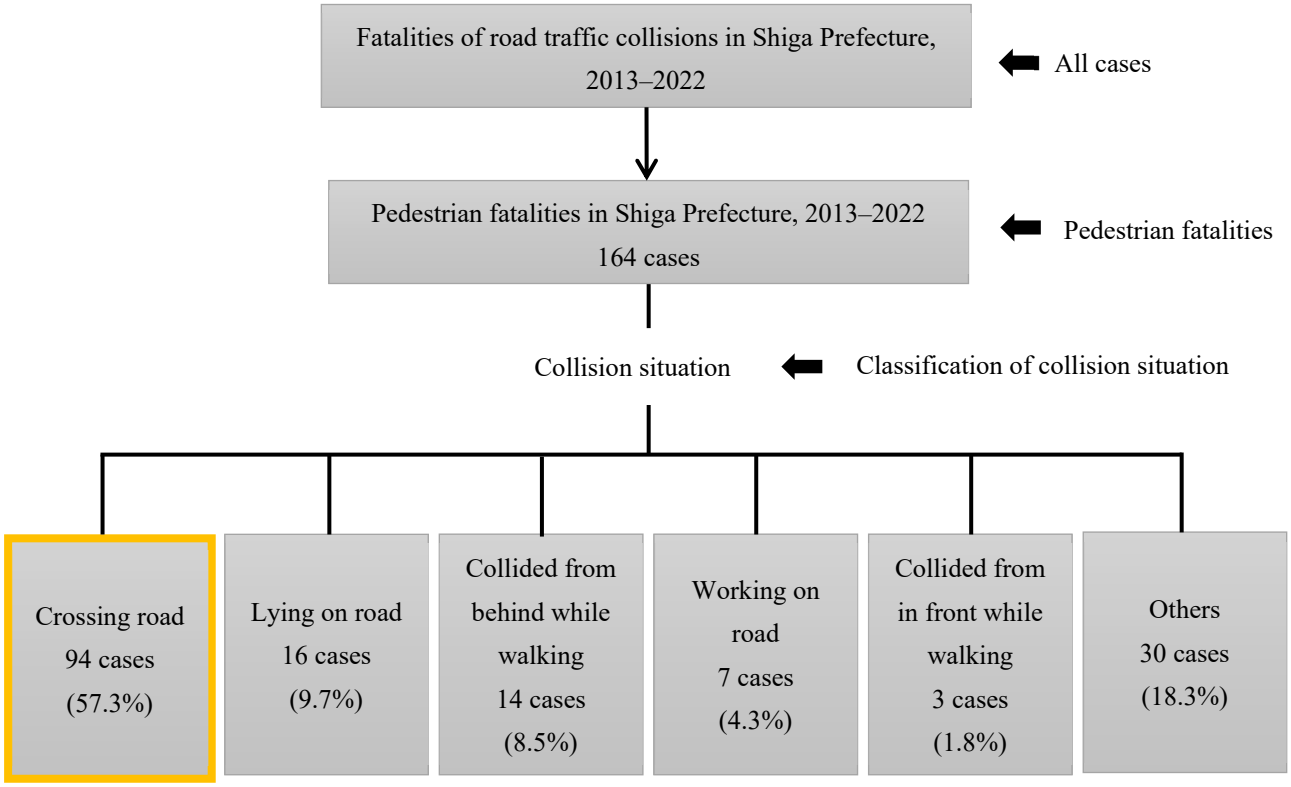


Figure 2. Flowchart of victim selection. The yellow frame shows the cases underwent further analyses.

4. Collision Scenarios

4.1. Classification of Collision Scenarios

Following the investigation of pedestrian behaviours and vehicle trajectories, we examined the collision scenarios. The most common scenario involved a pedestrian being struck while crossing a road (57.3%), followed by a pedestrian being struck while lying on a road (9.7%), a pedestrian being struck from behind while walking (8.5%), a pedestrian being struck while working on the road (4.3%), and a pedestrian being struck from the front while walking (1.8%) (Figure 2). Because collisions involving a pedestrian being struck while crossing a road represented the most common situation, the following analyses were performed for 94 such cases. Among them, 30 cases (31.9%) occurred at a crosswalk and 64 cases did not (68.1%).

4.2. Background Information Regarding Fatalities of Pedestrians Crossing Roads

Table 1 presents background information about the 94 fatal pedestrian road-crossing incidents. The majority of the victims (53.2%) were female, and the median age was 77 years (IQR: 64–83). In addition, 73.4% of the victims were aged 65 years or above; 64.9% of cases occurred at night. Regarding the location of the collisions, 68.1% of cases occurred outside of crosswalks, whereas 22.3% took place at crosswalks without signals. Regarding the direction of crossing, 61 pedestrians (64.9%) crossed from the oncoming traffic lane side to the vehicle's lane side (i.e., from right to left from the driver's perspective, as vehicles drive on the left in Japan), whereas 33 pedestrians (35.1%) crossed from the vehicle's lane side to the oncoming traffic lane side (i.e., from left to right from the driver's perspective). Regarding the vehicles involved, there were 39 cases involving a standard passenger vehicle, 40 involving a light passenger vehicle, 12 involving a large vehicle (including trucks), 2 involving a motorcycle, and 1 case involving an unknown vehicle type. The mean age of the driver was 45.9 ± 17.0 years (ranging from 18 to 90 years).

Table 1. Background information about cases involving pedestrians crossing roads.

Age		
	Median (IQR)	77 (64, 83)
	65 years old or more	69 (73.4%)
Sex		
	Male	44 (46.8%)
	Female	50 (53.2%)
Time of collision		
	Day (6–18)	33 (35.1%)
	Night (18–6)	61 (64.9%)
Place of collision		
	Crosswalk	30 (31.9%)
	With signal	9 (9.6%)
	Without signal	21 (22.3%)
	Others	64 (68.1%)
Crossing direction		
	From oncoming traffic lane side	61 (64.9%)
	From vehicle's lane side	33 (35.1%)

IQR: inter quartile range.

4.3. Analysis of Collision Site and Collision Speed by Crossing Direction

The cases involving an unknown vehicle or motorcycle were excluded from the analysis. For the remaining 91 cases, the offending drivers' characteristics were first examined. There were three drunken drivers with breath alcohol levels of 0.1 mg/L, 0.19 mg/L, and less than 0.15 mg/L, respectively. There were no illicit drug users. Additionally, no drivers suffered from dementia, visual impairment, or hearing loss at the collision. Next, comparisons were conducted according to the crossing direction. Regarding pedestrians, no significant difference in age or sex distribution was found between those crossing from the oncoming traffic lane side to the vehicle's lane side and crossing from the vehicle's lane side to the oncoming traffic lane side (Table 2).

Table 2. A comparison of the age distribution of pedestrians, sex distribution of the pedestrians, distributions of the most severely injured body regions, and mean collision speed between the two pedestrian crossing directions.

	From Vehicle's Lane Side (n = 33)	**From Oncoming Traffic Lane Side (n = 58)**	***p* Value**
Age (Median and IQR)	74 (63.0, 81.0)	78 (66.3, 88.0)	0.51
Sex (M:F)	18:15	24:34	0.23
Collision speed (km/h) (Median and IQR)	50 (35, 60)	50 (50, 60)	0.07
Most severely injured body region (n)			
Head	16 (48.5%)	32 (55.2%)	0.54
Neck	3 (9.1%)	3 (5.2%)	0.38
Chest	9 (27.3%)	11 (19.0%)	0.36
Abdomen	1 (3.0%)	2 (3.4%)	0.70
Hip	4 (12.1%)	8 (13.8%)	0.55
Lower extremities	0 (0%)	1 (1.7%)	0.64
Severe destruction	0 (0%)	1 (1.7%)	0.64
Width of road (n)			0.17
<6 m	8 (24.2%)	6 (10.3%)	
≥6, <11 m	23 (69.7%)	45 (77.6%)	
≥11 m	2 (6.1%)	7 (12.1%)	

Analysis of the most severely injured body region revealed that the head was the most commonly affected area (51.1%), followed by the chest (21.3%) and hip (12.8%). Combined, head and chest injuries accounted for nearly three-quarters of cases in both crossing directions, with no significant difference in their distributions between directions. Regarding the road width, collisions most commonly occurred on roads that were 6 m to 11 m wide, with no significant difference in distributions between crossing directions. An analysis of collision speeds revealed a tendency for higher speeds in cases in which pedestrians crossed from the oncoming traffic lane side to the vehicle's lane side, relative to the opposite direction ($p = 0.07$).

Figure 3 shows the distribution of collision sites on vehicles in relation to pedestrian crossing directions. Among those crossing from the vehicle's lane side to the oncoming traffic lane side, 54.5% (18 out of 33) were struck by the vehicle's proximal region (front left). In contrast, 39.7% (23 out of 58) of those crossing from the oncoming traffic lane side to the vehicle's lane side were struck by the vehicle's distal region (also front left). This difference was statistically significant ($p = 0.02$). Therefore, in both crossing directions, collisions most commonly involved the front left of the vehicle.

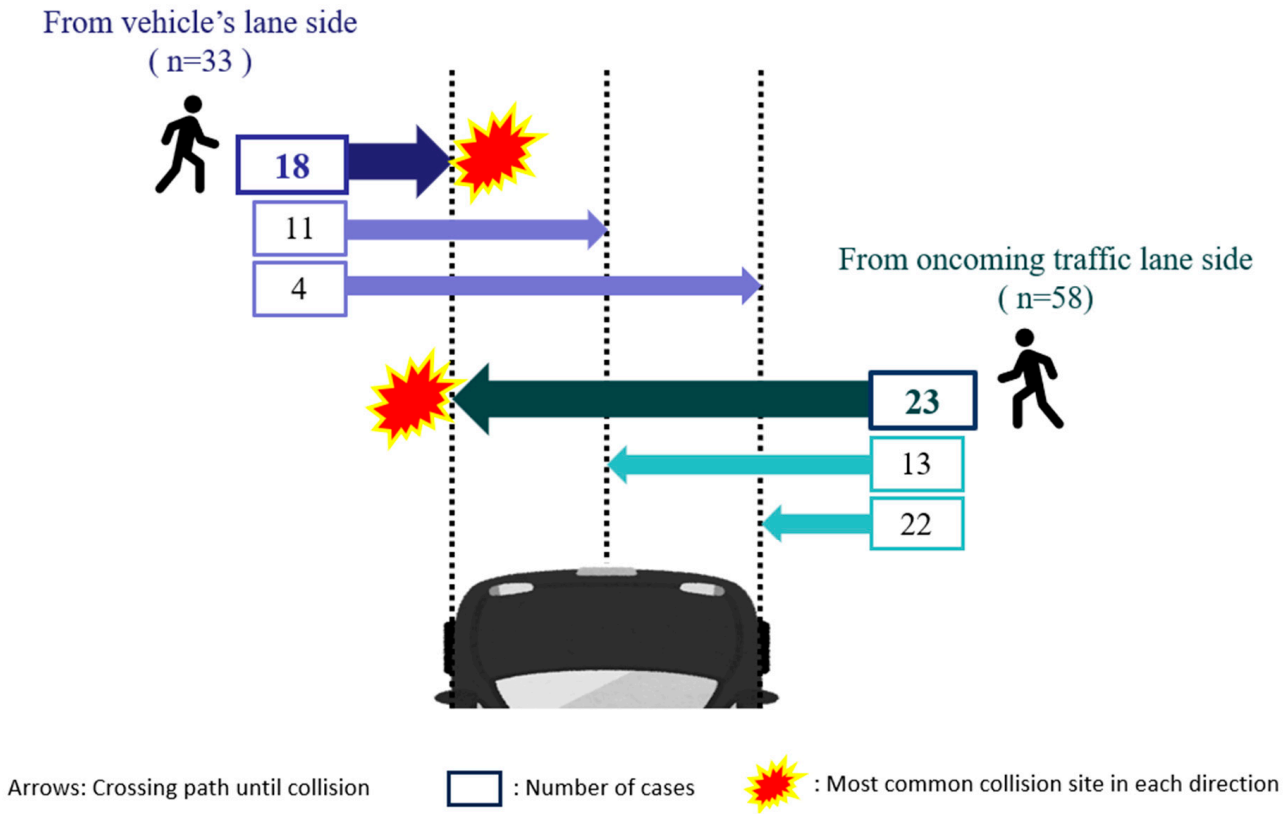


Figure 3. Distributions of the collision site of the vehicle for different pedestrian crossing directions.

Collision speeds at each vehicle impact site were compared between the two pedestrian crossing directions (Figure 4). For collisions involving the front centre and front right of the vehicle, the median collision speeds were higher when pedestrians crossed from the oncoming traffic lane side to the vehicle's lane side rather than from the vehicle's lane side to the oncoming traffic lane side. A significant difference in collision speed was observed for impacts at the centre of the vehicle ($p = 0.048$).

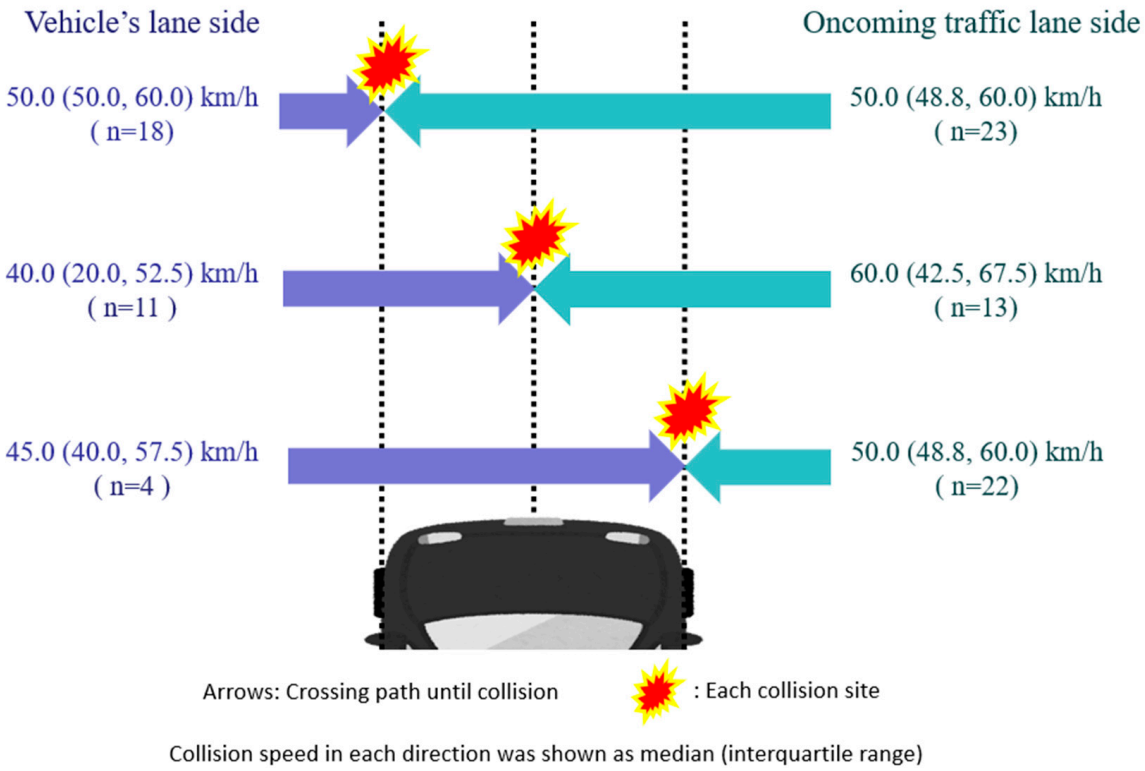


Figure 4. Comparisons of the collision speed for each collision site of the vehicle for the different crossing directions.

5. Discussion

In the present study, we examined the vehicle impact site, collision speed, most severely injured body regions of pedestrians, and crossing directions in cases of fatal crossing pedestrian–vehicle collisions. Although several existing studies have examined the characteristics of the situations between vehicles and crossing pedestrians, to the best of our knowledge no previous studies have focused on the parameters examined in the current study [14–17]. In one study, serious and fatal pedestrian injuries in Wichita, Kansas, were analysed [14]. According to analyses of road characteristics and vehicle behaviours, most collisions occurred on straight roads (95.8%) while vehicles were driving straight (76.1%). This pattern is similar to that observed in the current study. In another study, crossing pedestrian–vehicle interactions were investigated in an urban area of Milan [15]. The results suggested that crossing behaviour was based on three sequential phases: approaching, appraising, and crossing. Older pedestrians walked significantly slower than younger adults and took more time to evaluate the safety gap from the oncoming vehicle. In another study, the kinematics of traffic participants were obtained from driving videos collected in several countries [16]. The results revealed that pedestrians typically engaged in non-verbal communication with other road users, such as gazing, hand gestures, nodding, or changing their behaviours. At the point of crossing, more than 90% of pedestrians were found to use some form of communication to convey their intention to cross [16]. In a study of unsignalised intersections in Germany, information regarding crossing pedestrian and vehicle trajectories was obtained from drone recordings [17]. The results suggested that vehicle–pedestrian interactions differed between zebra crossings and unmarked crossings, with drivers tending to yield more to pedestrians at zebra crossings.

Regarding the collision situation in the present study, the majority of fatally injured pedestrians were older adults crossing the road at night. Among fatal injuries to pedestrians crossing a road, 31.9% occurred at crosswalks and 68.1% took place outside crosswalks. This

result is similar to the results of previous studies reporting that approximately one-third of fatal pedestrian collisions took place on crosswalks [18] and most pedestrian injuries in cities occurred when pedestrians crossed roads in unauthorised places [19]. Generally, road infrastructure—such as signals for crosswalks—and the purpose of the trip are key factors affecting the behaviour of pedestrians crossing a road [20]. Furthermore, lower traffic flow is associated with a higher possibility of pedestrians crossing directly at unauthorised sections of the road [8]. In the present study, the highest incidence of collisions occurred when pedestrians crossed the road illegally, highlighting the urgent need to educate older adults about safe crossing behaviours to reduce pedestrian fatalities [21]. Furthermore, most collisions occurred on rural roads narrower than 11 m. Previous research has shown that divided roads with barriers, designed for higher speeds, increase the fatality risk [22]. However, our results suggest that older pedestrians are also vulnerable to fatal collisions on rural roads, reflecting a challenging phenomenon for ageing societies.

This study confirmed the characteristics of pedestrians involved in fatal collisions while crossing the road. Previous research reported that older pedestrians are more cautious than younger adults when assessing gaps in traffic, and children are less able than teenagers or adults to make appropriate safe crossing decisions [23]. A survey study examining pedestrian preferences and behaviours found that older respondents valued safer facilities, such as zebra crossings and signalised intersections, more highly than younger respondents [24]. In contrast to the conclusions of these previous studies, the present results highlight a novel characteristic of increased risk among older pedestrian behaviours in more rural areas. Because Japan has experienced rapid population ageing in recent years compared with other countries, this trend may emerge in other developed countries in the near future.

Older pedestrians often make subjective judgements about crossing streets, frequently assuming that approaching drivers will be able to stop safely without hitting them. A previous report suggested that vehicle deceleration is an important indicator of whether pedestrians choose to cross a street [25]. As vehicle speed and distance between the vehicle and person are closely related to deceleration, crossing decisions are typically made on the basis of visual assessment of these factors. A previous report mentioned that a walking speed of 1.0 m/s is necessary for pedestrians to cross safely in Japan [26]. This walking speed is considered to be essential for maintaining normal outdoor activities. However, as people age, their lower-limb physical function tends to decline, resulting in slower walking speeds. Thus, there may be a mismatch between what older adults would like to do and what they are able to do in daily life. Furthermore, ageing is associated with a loss of eyesight and hearing as well as poor coordination. These factors might lead to misjudgements when crossing roads. Another common cause is failing to check in both directions before crossing. With increasing age, higher brain dysfunction often occurs, particularly attention dysfunction caused by damage to the frontal lobe.

Poor outcomes are generally related to increasing age, with older individuals at a greater risk of sustaining severe injuries, particularly to the brain and chest [27–31]. In addition to having more fragile bodies than younger people, older adults often have reduced physiological resilience and are more prone to complications, which may contribute to worse outcomes. This trend is in accordance with the current findings, in which the most severely injured body region was the head, followed by the chest.

In the current study, female pedestrians accounted for the majority of fatalities related to road crossings (53.2%). This trend differs from the results of some previous studies. For instance, a cross-sectional and spatial analysis conducted in West Virginia revealed that 70% of pedestrians in fatal collisions were male [32], and a study conducted in 10 states by the Federal Highway Administration found that 69% of pedestrian fatalities were male [33].

A study examining road-crossing behaviours at intersections found that males were three times as likely as females to cross the street during high-risk situations [34]. This male predominance was attributed to females engaging in safer traffic behaviours and taking fewer risks. However, in Japan, there are more women than men (63.7 million women vs. 60.5 million men), and this trend is particularly clear among older people aged 65 years and older (20.5 million women vs. 15.7 million men) [35]. In this context, the number of fatalities of pedestrians aged 65 years and above was 373 for females and 314 for males. Therefore, the predominance of female pedestrian fatalities may reflect the demographic characteristics of Japan's ageing society.

A novel aspect of the present study is that we investigated the collision characteristics of older pedestrians according to the direction of the collision. Although previous research has examined differences in collision speed, injury severity, and hospital mortality between pedestrians crossing on crosswalks versus non-crosswalk locations, to the best of our knowledge, no prior study has investigated collision and injury characteristics on the basis of the crossing direction in real-world vehicle–pedestrian collisions, as presented in the present study [36–41]. A key finding of the current study is that pedestrians crossing from the vehicle's lane side were more often struck by the near side of the vehicle's front, whereas those crossing from the oncoming traffic lane side were more often struck by the far side. This suggests that drivers may pay more attention to the vehicle's lane side and have greater difficulty noticing pedestrians approaching from the oncoming lane. Thus, collisions involving pedestrians crossing from the oncoming traffic lane side tended to be more serious than those involving vehicle's lane side crossings. This trend is particularly evident when comparing collision speeds across different vehicle impact sites. These patterns are likely to be caused by drivers paying more attention to pedestrians on the vehicle's lane side than those on the oncoming traffic lane side. Therefore, raising driver awareness of this issue—particularly the awareness that older pedestrians may cross from the oncoming traffic lane side—could be helpful for preventing future collisions and enhancing road safety in ageing societies.

The present results may also contribute to the development of autonomous driving technologies. First, the kinematic patterns exhibited by pedestrians reported in the present study might inform approaches to improving pedestrian detection. Recently, advanced driver assistance systems have been implemented in many vehicles. These systems include pedestrian detection in front of the vehicle, providing warnings for the driver and initiation of automatic emergency braking if the driver does not respond. Although these systems detect pedestrians in front of the vehicle, the present results suggest that detecting pedestrians crossing the oncoming traffic lane would also be valuable in preventing collisions. Additionally, the collision speed results in the present study may be useful for informing the development of forced braking systems. Our results revealed that the median collision speed was 50 km/h (IQR: 35–60 km/h) for pedestrians crossing from the vehicle's lane side and 50 km/h (IQR: 50–60 km/h) for those crossing from the oncoming traffic lane side. According to vehicle–pedestrian collision analyses in Japan, the risk of a pedestrian fatality increases markedly at a collision speed of 40 km/h or higher [42]. Other studies have suggested that at a collision speed of 50 km/h, the risk of fatal injury to a pedestrian is more than twice the risk at 40 km/h and five to eight times that at a speed of 30 km/h [43,44]. Therefore, to prevent fatal injuries, an appropriate goal for the early detection of pedestrians crossing the road is to decrease the collision speed to less than 30 km/h, even if the collision itself cannot be avoided. When detecting crossing pedestrians, if the distance between the pedestrian and the vehicle is too short, autonomous braking could be activated regardless of the driver's response.

In the current study, a retrospective analysis was conducted using a decade-long dataset of a representative area to monitor the trends of MVCs. However, sustained measures for preventing MVCs are required. Investigating circumstances and environments of collisions and summarising them may contribute to the establishment of effective measures. If specific areas with repeated MVCs are found, the improvement of the infrastructure of the area should be promoted. Simultaneously, comprehensive lists of existing measures that could provide solutions should be created. Furthermore, the sustainable monitoring of trends can be used to examine potential preventive measures and assess the promotion or modification of measures. Therefore, further investigations including multiple factors related to pedestrian–vehicle collisions could be continuously performed by the local government responsible for maintaining safety in the region. Such an approach might provide effective countermeasures for preventing fatal MVCs in multiple areas (e.g., improving the safety of the environment, enhancing safety education for both drivers and pedestrians, and implementing technical innovations for collision avoidance). Consequently, rapid reductions in MVC casualties might be achieved.

The present study involved several limitations. First, the study was performed in Shiga Prefecture as a representative region of Japan. This study area was selected because the distribution of road-user fatalities in this area closely mirrors national trends in Japan. However, a previous study suggested that there is an urban–rural difference in the characteristics of MVCs involving pedestrians [1]. The study reported that without access to a personal vehicle or public transportation, many individuals in rural areas must walk to conduct activities of daily living, which increases their risk of being involved in an MVC [1]. Similar studies should be conducted in multiple prefectures to conduct comparisons between urban and rural areas and to confirm the present results. Furthermore, comparative study with other areas would supplement the evaluation of each measure and promote effective measures in all areas. Second, the medical histories of each pedestrian were not obtained in the present study. Poor coordination of movements, limited mobility, cognitive impairments, and other conditions may affect a person's ability to cross the road. Furthermore, these factors may also influence an individual's communication behaviours regarding their intention to cross the road. Further studies including this information should be conducted. Third, although some information about the offending drivers, such as age, use of alcohol or illicit drugs, history of dementia, visual impairment, and hearing loss was recorded, we did not obtain other detailed information about the drivers. Moreover, differences in the causes of collision, such as a loss of attention, drowsiness, mobile phone use, and the use of psychotropic medicines, may have affected the findings of the present study. Further research should therefore include driver information. Fourth, the relationships between environmental factors and MVCs were not fully considered in this study. Although the time of collision, place of collision, and road width were examined, other factors, such as weather conditions, road illumination, and intensity of traffic in the lane may influence the occurrence of MVCs. Further studies including these factors may be helpful for confirming the present findings.

6. Conclusions

The current study reviewed all pedestrian fatalities resulting from MVCs in Shiga Prefecture, Japan, between 2013 and 2022. Among the 164 pedestrian fatalities (involving 92 males and 72 females), the most common scenario was a collision occurring when a pedestrian crossed a road, accounting for 57.3% of cases. Among these cases, 61 pedestrians (64.9%) crossed from the oncoming traffic lane side to the vehicle's lane side, whereas 33 pedestrians (35.1%) crossed from the vehicle's lane side to the oncoming traffic lane side. Notably, 54.5% of pedestrians crossing from the vehicle's lane side were struck by the near

side of the front of the vehicle, whereas 39.7% of those crossing from the oncoming traffic lane side were hit on the far side of the front of the vehicle ($p = 0.02$). Therefore, for both crossing directions, collisions frequently involved the front left of the vehicle. For impact sites at the front centre and front right of the vehicle, the collision speeds were higher when pedestrians crossed from the oncoming traffic lane side to the vehicle's lane side rather than the reverse. A significant difference in collision speed was found for collisions involving the front centre of the vehicle ($p = 0.048$). These findings suggest that greater driver awareness of older pedestrians crossing from the oncoming traffic lane side may help prevent collisions. There is a compelling need for the worldwide implementation of effective pedestrian fatality mitigation and collision avoidance countermeasures. With the advancement of autonomous driving technologies, the ability to detect and avoid pedestrians has become essential. We expect our results to contribute to the monitoring of pedestrian behaviours oncoming traffic lane side and systems for automated braking or steering of the vehicle.

Author Contributions: M.Y. designed the study, analysed the data, and drafted the manuscript. M.H. designed the study and drafted the manuscript. A.T. analysed the data and performed statistical analyses. S.M. analysed the data. M.N. reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Shiga University of Medical Science (2014-186).

Data Availability Statement: The data presented in this study are available upon request from the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

MVC Motor vehicle collision

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