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Older Pedestrians Hit by Motor Vehicles in South Australia

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Abstract

Older pedestrians are vulnerable road users. To highlight the road safety issues for older pedestrians and identify countermeasures to improve their safety, this study examined the number of older pedestrians hit by motor vehicles in South Australia, the characteristics of their collisions and their injury outcomes. Police-reported data (2008-2017) for 3,493 pedestrians hit by vehicles were analysed, along with hospital data (January 2008-November 2010 and June 2014-August 2017) for 360 pedestrians hit by vehicles and seriously injured. Fewer older pedestrians (two age groups: 65-74 and ⩾75) were hit by motor vehicles between 2008 and 2017 than younger adult pedestrians (18-64). However, they had higher rates of being seriously or fatally injured and those aged ⩾75 had higher rates of being hit per 100,000 population than younger adult pedestrians (18-64). Older pedestrians were less likely than younger adult pedestrians to have consumed alcohol (⩾75=5%, 65-74=9%, 18-64=37%) or be responsible for the crash (⩾75=36%, 65-74=30%, 18-64=48%). They were also more commonly walking on the footpath when hit than younger adult pedestrians (⩾75=17%, 65-74=15%, 18-64=10%), who were more commonly walking on the road (⩾75=9%, 65-74=9%, 18-64=15%). Older pedestrians were more likely to be hit between 6am and 6pm (⩾75=88%, 65-74=79%, 18-64=58%) than younger adult pedestrians, who were more likely hit between 6pm and 6am (⩾75=12%, 65-74=21%, 18-64=42%). Seriously injured pedestrians in the three age groups did not differ in injury severity (Injury Severity Scale, p=.062), but older pedestrians were more likely to spend longer than 10 days in hospital (⩾75=46%, 65-74=44%, 18-64=25%, p=.031). Infrastructure, speed, and vehicle-based countermeasures are discussed.

Key Findings

- Older pedestrians (aged ⩾65) hit by motor vehicles in South Australia were examined.
- They had a higher risk of serious or fatal injury than pedestrians aged 18-64.
- They were more likely to spend ten days or longer in hospital if seriously injured than pedestrians aged 18-64.
- They were less likely to have consumed alcohol or be responsible for the crash than pedestrians aged 18-64.
- Pedestrians aged ⩾75 had more crashes per 100,000 population than those aged 18-74.

Introduction

Walking is a beneficial activity: it improves personal health, well-being, fitness, life expectancy and social participation; it reduces illness and disease; and it does not have the financial costs associated with other forms of travel (Gordon-Larsen et al., 2009; Hamer & Chida, 2008; Netz et al., 2005; Oxley, 2009; Wannamethee et al., 1998; Wen et al., 2011). It is also beneficial to the broader community, as it is environmentally friendly, and reduces traffic congestion and the costs to society of illness, disease, and ageing (Oxley, 2009). It is an important way of getting around for older

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Glossary

AIS – Abbreviated Injury Scale

BAC – Blood Alcohol Concentration

ISS – Injury Severity Scale

MAIS – Maximum Abbreviated Injury Scale

MDMA – Methylenedioxymethamphetamine

OECD – Organisation for Economic Co-operation and Development

RAH – Royal Adelaide Hospital

SA – South Australia

TARS – Traffic Accident Reporting System

THC – Tetrahydrocannabinol

adults, especially as they are becoming increasingly healthier than past generations and are participating in more activities outside of the house (BITRE, 2014; Burkhardt & McGavock, 1999; Christensen et al., 2013; Heikkinen et al., 2011; Hjorthol et al., 2010; Hu et al., 2000; König et al., 2018; Lyman et al., 2002; OECD, 2001).

Despite these benefits, walking is a mode of transport with an increased risk of serious and fatal injuries for older adults compared to people in other age groups. Oxley (2009) compared rates of pedestrian deaths per 100,000 population by age group. It was found that pedestrians aged 70 years and older had the highest rates. Martin, Hand, Trace, and O'Neill (2010) demonstrated that pedestrians aged 65 and over are more than twice as likely as those aged 16 to 64 to be killed when hit by a vehicle. Recent research in Australia by Baldock, Thompson, Dutschke, Kloeden, Lindsay, and Woolley (2016) showed that the proportion of pedestrians who died as a result of a crash was almost three times higher for those aged 75 and over compared to those aged under 60 (9% vs 3.2%). Pedestrians also had the highest rates of fatalities from crashes compared to other road users (e.g., car, bus, motorcycle, bicycle) across all ages. Indeed, Elvik (2009) has shown that, irrespective of age, the risk of an injury when walking is about four times higher than when driving a car. Other research (Langford & Koppel, 2006; OECD, 2001) has shown that older adults are at a higher risk of being killed as pedestrians than as car drivers on a per trip basis.

This increased risk for older pedestrians is partly due to their fragility. They are more likely to be severely or fatally injured if they are struck by a car or fall (OECD, 2001; Oxley, 2009; Uddin & Ahmed, 2018). They may also have an increased risk of being involved in collisions due to declines in their health or cognitive and functional abilities. A complex level of cognitive and perceptual processing is required by a pedestrian when negotiating the road environment. The ability to integrate the speed and distance of an approaching vehicle is critical when crossing the road. A reasonable level of physical ability is also crucial and deteriorating health or cognitive and functional abilities with age can make it substantially more difficult to negotiate the road environment safely as a pedestrian (Dommes & Cavallo, 2011; OECD, 2001; Oxley et al., 2005; Tournier et al., 2016). Even normal ageing leads to some reduction in physical and cognitive functioning, while some older adults have significant declines in these areas.

The difficulties that older pedestrians encounter when crossing the road have been highlighted in many studies (Carthy et al., 1995; Choi et al., 2019; Dommes, 2019; Dommes et al., 2012, 2013; Lobjois & Cavallo, 2007, 2009; Oxley, 2000; Oxley et al., 1997, 1999, 2005). They include

1. crossing wide roads with numerous lanes;
2. crossing at confusing intersections;
3. crossing in busy or fast-moving traffic;
4. detecting an oncoming vehicle or correctly judging its speed; and
5. selecting adequate gaps to accommodate their slower walking speed, particularly in complex two-direction traffic under time pressure.

Other studies (Amosun et al., 2007; Asher et al., 2012; Langlois et al., 1997; Romero-Ortuno et al., 2010) have shown that standard crossing times at signalised pedestrian crossings are insufficient to accommodate the slower walking speed of older people. This suggests that the increased risk for older pedestrians may also be partly due to the design and organisation of road systems.

Consequently, older pedestrians are a vulnerable road user group. The present study involved a thorough investigation into the number of older pedestrians (two age groups: 65 to 74 years and 75 years and over) hit by motor vehicles in South Australia (SA), with comparisons made to the number of younger adult pedestrians (18 to 64 years) hit by motor vehicles. The characteristics of their collisions and injury outcomes were also examined and compared. Data from two sources were analysed: police-reported data for crashes in SA between the years of 2008 and 2017 and data from the Royal Adelaide Hospital (RAH) in SA for admissions from crashes for two time periods (January 2008 to November 2010 and June 2014 to August 2017).

Methods

Police-reported pedestrian crash data

Crash data for a 10-year period (2008 to 2017) were obtained from the Traffic Accident Reporting System (TARS), which is a database of all de-identified police-reported crashes in SA that is managed by the Department for Infrastructure and Transport and which is available to the Centre for Automotive Safety Research through a long standing agreement. This 10-year period was chosen as it is consistent with the period available for data from the RAH also used in this study (see below). TARS records: details of the nature, cause, time and location of a crash; details of all drivers and any injured occupants or pedestrians involved; and the severity of any resulting injuries.

Population data by age for SA were obtained from the Australian Bureau of Statistics for 2008 to 2017 (Australian Bureau of Statistics, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018). The total annual population by age was calculated from these data. This was then used to calculate the rates of pedestrians hit by motor vehicles per 100,000 head of population for each year of investigation.

The data extracted from TARS and used in the analyses only included crashes in which a pedestrian was hit by a road-based motor vehicle. Pedestrian falls and collisions with bicycles, mobility scooters, wheelchairs, skateboards, trains or trams were not included. Demographic information for the pedestrian (age, sex) were obtained, along with specific details of the crash which included: the severity of the pedestrian injury, the date, time and lighting conditions (day or night) when they were hit, speed limit at the location, and the pedestrian's Blood Alcohol Concentration (BAC), pedestrian's responsibility for the crash, specific error by the pedestrian, and pedestrian movement prior to being hit. Injury severity was recorded as one of five levels: no injury, injury requiring treatment from a private doctor, injury requiring treatment at a hospital, injury requiring admission to a hospital, and fatal injury. For the current analyses, a serious injury was defined as one requiring hospital admission.

To analyse the crash data in terms of the age group of the pedestrians involved, it was necessary to base the analysis on crash-involved pedestrians rather than crashes. The consequence of using these data is that, for crashes involving multiple pedestrians, each pedestrian had a separate entry in the database. Therefore, a single crash that involved two pedestrians was counted as two pedestrians in the data. Crashes involving multiple pedestrians were found in 141 (4.2%) of the total 3,321 individual crashes in the sample.

The crash and population data were organised by age into the following groups: 18 to 64 years, 65 to 74 years and 75 years and over. Two older age groups were examined as it was thought that comparisons between younger older pedestrians (65 to 74) and an older group of older pedestrians (75 and over) would yield interesting results. Pedestrians aged 18 to 64 were chosen as the comparison group as they were younger than 65 but still adults, which meant that they would have an experienced understanding of the road system and less vulnerability to physical trauma compared to children. Data were excluded from the analyses if the age of the pedestrian was not recorded.

Analyses

The data were firstly examined in terms of the total number of pedestrians hit by motor vehicles in SA, as well as the rates of pedestrians hit per 100,000 population and the proportions of the pedestrians who were seriously or fatally injured, in each age group separately and for each year between 2008 and 2017. The pedestrian sample was examined next in terms of the male/female sex composition and the involvement of certain variables relating to the characteristics of the collisions they were involved in (pedestrian BAC, pedestrian responsibility, specific error by the pedestrian, and pedestrian movement prior to being hit, as well as the day of the week, time of day and lighting conditions when they were hit, and speed limit at the location). Statistical significance was not calculated due to the very large sample of 10 years of crash data that were used. Analyses from such a sample would be likely to find even very small group differences statistically significant, but this does not imply that they would be meaningfully significant (i.e., substantial road safety issue). That is, this study was designed to identify large, practically meaningful differences that may be important for policy development, rather than merely identifying small group differences that are unlikely to have occurred by chance.

Admissions data from the RAH

Data were collected for pedestrians who had been injured in a collision with a motor vehicle and admitted (four hours or more) to the RAH during two time periods, January 2008 to November 2010 and June 2014 to August 2017. Data were not collected between these periods due to staffing resources. The total sample of injured pedestrians was 360. These included 262 (72.8%) pedestrians aged 18 to 64 years, 44 (12.2%) aged 65 to 74, and 54 (15.0%) aged 75 and over. Data were collected and matched for each pedestrian and included: medical assessments and interventions undertaken during hospitalisation and Forensic Science SA data related to mandatory testing for alcohol and drugs. A researcher from the Centre for Automotive Safety Research attended the RAH to collect hospital data that were linked to alcohol and drug tests data through details of the crash (e.g., date) and the participants (e.g., date of birth, driver license number). The collection of medical data by CASR is permitted in accordance with Part 7 of the *SA Health Care Act 2008*, which lists CASR as an authorised entity gazetted for research activity. The use of medical data for this project was additionally approved by the Central Adelaide Local Health Network Human Research Ethics Committee (HREC/14/RAH/356).

Medical data

Medical data included ambulance records, emergency department records, and hospital in-patient records. Ambulance records included information about the crash collected at the scene and the initial care of the injured participants. Emergency department records included injury surveys. Hospital in-patient records included patient demographics, injury and medical intervention information, and discharge details.

Injuries were coded according to the Abbreviated Injury Scale (AIS), which was developed by the Association for the Advancement of Automotive Medicine to classify the threat to life associated with injuries. Each separate injury is given a score on a scale from one (minor) to six (currently untreatable) and is categorised by the body region in which it occurred (six regions: abdomen, chest, external, extremities, face and head/neck). A maximum AIS (MAIS) was also coded for the injury with the highest AIS score within each separate body region, as a person may receive a number of separate injuries to a specific region.

Each injured person's AIS scores were converted to an Injury Severity Score (ISS) to provide an overall measure of injury severity. ISS is calculated by taking the three most severely injured body regions, squaring the score given to the most severe injury and summing these numbers. Only scores one to five are used, giving a maximum ISS of 75. If any injury has an AIS score of six (untreatable), ISS is automatically set to the maximum 75.

Blood tests for alcohol and drugs

Since 1972 in SA, drivers, motorcycle riders, vehicle occupants and pedestrians over the age of 14 years, who present to hospital as a result of a crash, have been required to undergo testing for blood alcohol concentration (BAC). Since July 2008, road users have also been screened for three illicit drugs: Methamphetamine, Delta-9-Tetrahydrocannabinol (THC) and 3,4-Methylenedioxymethamphetamine (MDMA). Blood samples must be taken within eight hours following the crash (usually within an hour or two) and tested by Forensic Science SA. These results in de-identified form were made available for this study.

Analyses

The sex composition of the sample of seriously injured older pedestrians (two age groups: 65 to 74 and 75 and over), along with the results of their blood tests for alcohol and drugs and their injury patterns and severity (length of hospitalisation, ISS, MAIS by body region), were examined, and comparisons made to younger adult pedestrians (aged 18 to 64). Frequency counts, means, chi-square tests and a non-parametric Kruskal-Wallis test were used. For all analyses, an alpha level of 0.05 was used for statistical significance. Cases were excluded:

1. where the pedestrian was hit by something other than a motor vehicle (i.e., bicycle, mobility scooter, wheelchair, skateboard, train, tram);
2. where the pedestrian was hit by their own vehicle;
3. where the pedestrian was hit while getting in or out of their own vehicle;
4. where the pedestrian deliberately intended to be hit as a suicide attempt (confirmed or suspected) or an act of self-harm; and
5. where hitting the pedestrian was a deliberate act by the driver.

Pedestrians lying on the road when hit by a vehicle were included in the analyses, as these collisions would not necessarily be the result of a deliberate suicide attempt by the pedestrian but could be related to other causes of interest, such as alcohol intoxication.

Results

Police-reported pedestrian crash data

The data included a total of 3,493 pedestrians hit by motor vehicles over the 10 years. The age of 3,241 (92.8%) was recorded, with 343 aged 75 years or older, 269 aged between 65 and 74 years and 2,077 aged between 18 and 64 years.

Overall crash involvement of pedestrians

The total numbers of pedestrians hit by motor vehicles in SA for each year from 2008 to 2017 are presented in Figure 1(a) for the three age groups separately (18 to 64, 65 to 74 and 75 and over). This provides an assessment of the overall quantum of pedestrians hit by motor vehicles. While there was a decrease in pedestrians aged 18 to 64 who were hit between 2008 and 2015, there was an increase from 2015 to 2017. In comparison, the numbers were steady for the two older groups over the 10 years, with the 65 to 74 group ranging between 22 and 34 each year and the 75 and over group ranging between 27 and 42.

Rates of pedestrians hit by motor vehicles per 100,000 population were calculated by age group for each year between 2008 and 2017 to account for differences between the groups in population. The rates (Figure 1(b)) declined over the 10 years in all three groups. Rates for the 18 to 64 and 65 to 74 groups were similar across the years, while the rate for the oldest group (75+) was higher than the rates for the other two groups in eight out of the ten years.

Proportions of the pedestrians who were seriously or fatally injured were calculated for each year. This was done for the 18 to 64 group and the two older groups combined into a 65 and over group (because the seriously and fatally injured numbers for the groups separately were low for individual years). This provides a comparison between older and younger adult pedestrians of the likelihood of being seriously or fatally injured if hit by a motor vehicle. Figure 1(c) shows the considerable variation in the proportions between the years for both groups. Overall, however, older

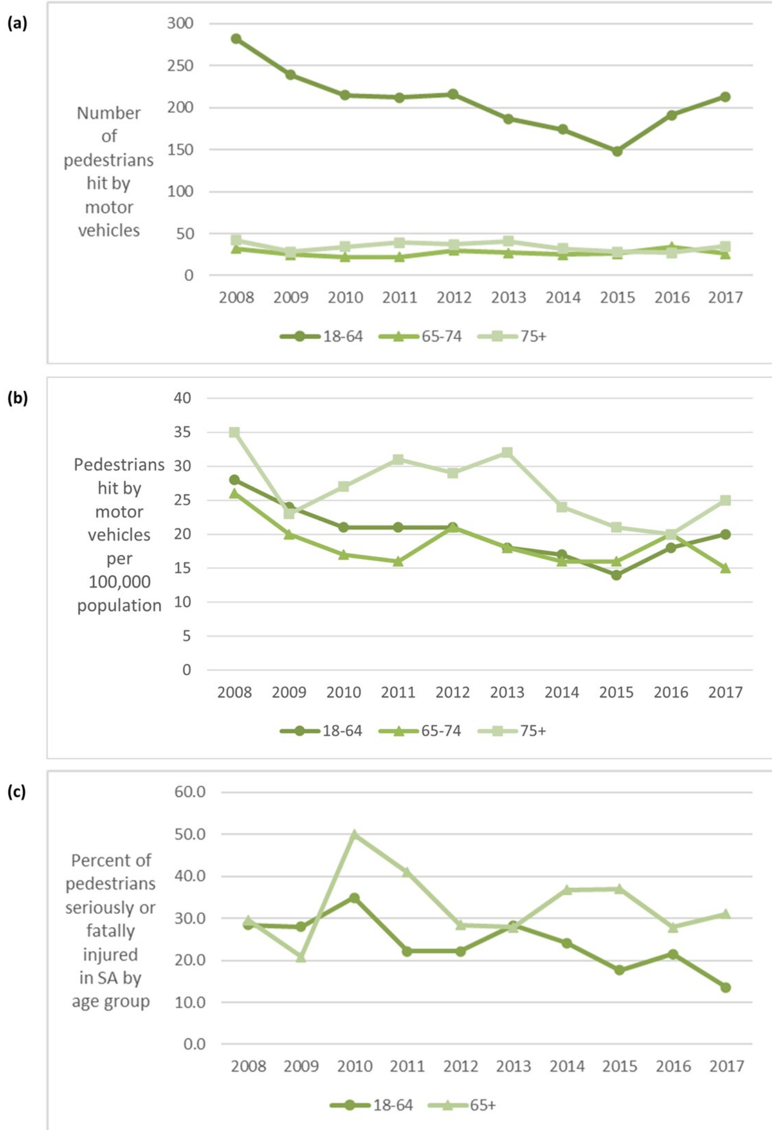

Figure 1. (a) Total pedestrians hiit by motor vehicles, (b) pedestrians hit by motor vehicles per 100,000 population and (c) proportions of pedestrians seriously or fatally injured in SA by age group between 2008 and 2017

pedestrians had a higher likelihood of serious or fatal injury than younger adult pedestrians in eight out of the ten years. Despite the year-to-year variation, the trend over the 10 years was steady for older pedestrians but showed decline in the likelihood of serious or fatal injury for younger pedestrians, particularly between 2013 and 2017.

Sex of crash-involved pedestrians

Sex was recorded for all pedestrians in the data. Of the 343 pedestrians aged 75 years or older who were hit by vehicles, 175 (51.0%) were female and 168 (49.0%) were male. Of the 269 who were aged 65 to 74, 132 (49.1%) were female and 137 (50.9%) were male. Of the 2,077 who were between 18 and 64, 919 (44.2%) were female and 1,158 (55.8%) were male. Therefore, the composition of the two older age groups were similar in terms of sex, with even numbers of males and females. Males appear slightly over-represented among younger pedestrians hit by motor vehicles.

Crash characteristics

BAC was known for 776 (22.2%) of the 3,493 pedestrians in the data set. Of the 97 pedestrians aged 75 or over for whom BAC was known, five (5.2%) were found to have alcohol in their system. Of the 66 aged between 65 and 74 for whom BAC was known, six (9.1%) had alcohol in their system. In comparison, of the 529 aged 18 to 64 for whom BAC was known, 196 (37.1%) had alcohol in their system. This indicates that older pedestrians may be less likely than younger adult pedestrians to have consumed alcohol when they have collisions with motor vehicles.

One hundred and twenty-two (35.6%) pedestrians aged 75 and over were found to be responsible for their crash, while 221 (64.4%) were not responsible. Eighty (29.7%) of those aged 65 to 74 were responsible, while 189 (70.3%) were not responsible. In comparison, 1,000 (48.1%) of those aged 18 to 64 were responsible, while 1,077 (51.9%) were not responsible. This suggests that older pedestrians may be less commonly found to be responsible for their collisions with vehicles than younger adult pedestrians, but also that older pedestrians aged 75 and over may be more commonly found to be responsible than older pedestrians aged 65 to 74.

In Table 1, the three age groups of pedestrians are compared in terms of other characteristics of their collisions with vehicles. In terms of the specific errors they made, older pedestrians were less commonly found to have caused the crash due to having consumed alcohol or not paying attention compared to younger adult pedestrians.

With regard to the movements of the pedestrians preceding the collision, the distributions (Table 1) were similar between groups, except older pedestrians were more commonly walking on the footpath when hit by a motor vehicle, while younger adult pedestrians were more commonly on the road. It should be noted, however, that almost half of the pedestrians from all three age groups were hit by vehicles while they were crossing the road without traffic signals or a pedestrian crossing. The specific errors made by the 1,168 pedestrians who were crossing without traffic signals or a pedestrian crossing were examined and the most common error was inattention (inattention = 699 (59.8%), drunken pedestrian = 87 (7.4%), disobey – traffic lights = 5 (0.4%), no errors = 377 (32.3%)).

Table 1 also shows that older pedestrians were more likely to be hit on Fridays, from 6 am to 6 pm and during daylight conditions compared to younger adult pedestrians, who were more likely to be hit on Sundays, between the hours of 6 pm and 6 am and during night-time lighting conditions. Also, of note, pedestrians from all three age groups were mostly hit by vehicles in areas with speed limits of 50 and 60 km/h. However, there is a slight tendency for the oldest group (75+) to be more commonly hit by vehicles in 60 km/h speed limits compared to those aged 18 to 74, who may be more commonly hit in 50 km/h speed limits.

Admissions data from the RAH

Sex of seriously injured pedestrians

Of the 54 seriously injured pedestrians aged 75 years or older, 24 (44.4%) were male and 30 (55.6%) were female. Of the 44 aged 65 to 74, 24 (54.5%) were male and 20 (45.5%) were female. In comparison, of the 262 aged 18 to 64, 156 (59.5%) were male and 106 (40.5%) were female. The differences between these groups in the numbers of males and females were not statistically significant ($x^2(2) = 4.2$, p = 0.120).

Results of blood tests for alcohol and drugs

Of the 30 pedestrians aged 75 and over for whom BAC was known, one (3.3%) had some level of alcohol in their system. Of the 23 pedestrians aged 65 to 74 for whom BAC was known, four (17.4%) had alcohol in their system. In comparison, of the 160 pedestrians aged 18 to 64 for whom BAC was known, 77 (48.1%) had alcohol in their system. The differences between the groups were statistically significant ($x^2(2) = 26.3$, p < 0.001). Older pedestrians were less likely to have consumed alcohol prior to being hit by a vehicle than younger adult pedestrians.

Drug screening results (tests for THC, methamphetamine and MDMA) were unknown/not conducted for 215 (59.7%) of the 360 seriously injured pedestrians. Of the results that were known, only 15 (10.3%) pedestrians tested positive to an illicit drug, and none were in the older groups (65 to 74 or 75 and over).

Examining injury patterns and severity

Table 2 presents the distribution of length of hospitalisation (in days) for the three age groups of pedestrians who were seriously injured from being hit by a vehicle. This only includes those who were hospitalised; it takes no account of the proportion of pedestrians involved in injury crashes who were not injured severely enough themselves to attend hospital. Also, cases in which the pedestrian died after a period of hospitalisation were excluded. The most common length of hospitalisation for younger adult pedestrians was one to five days (36.9%), while, for older pedestrians, it was longer than ten days (75 and over = 46.0%, 65 to 74 = 43.9%). The differences between the distributions were statistically significant ($x^2(6) = 13.9$, p = 0.031). Seriously injured older pedestrians were more likely to be hospitalised for longer periods than seriously injured younger adult pedestrians, which suggests they took longer to recover from their injuries.

The hospital data did not include AIS scoring of injuries for the 2008 to 2010 period. Therefore, only data from the 2014 to 2017 period were used to compare ISS between the three groups. These data did not meet parametric assumptions (data were skewed and contained outliers and sample sizes were unequal). ISS scores for the 75 and over (median = 11) and 65 to 74 (median = 9) groups were slightly higher than the scores for the 18 to 64 group (median = 5). A non-parametric Kruskal-Wallis test for independent samples was performed on ISS for the three groups, which showed that the differences between the groups approached statistical significance (Kruskal-Wallis $x^2(2) = 5.6$, p = 0.062).

MAIS for each of the six AIS body regions for pedestrians aged 75 and over, 65 to 74 and 18 to 64 are shown in Table 3. Again, only data from 2014 to 2017 were used. The distribution of injuries by body region was similar for each group. The body regions that featured most prominently for pedestrians aged 75 and over were external regions (22 cases), the head/neck (18 cases) and the extremities (10 cases). For those aged 65 to 74, the most common regions were external regions (17 cases), the extremities (16 cases) and the head/neck (11 cases). For those aged 18 to 64, the most common regions were external regions (73 cases), the extremities (57 cases) and the head/neck (47 cases). It should be noted, however, that almost all injuries to external regions were of low severity (MAIS of 1). The least com-

Table 1. Pedestrians in three age groups compared in terms of the characteristics of their crashes with vehicles

	75 and over	65 to 74	18 to 64
Pedestrian error			
Disobey – traffic lights	5 (1.5%)	9 (3.3%)	80 (3.9%)
Drunken pedestrian	3 (0.9%)	3 (1.1%)	144 (6.9%)
Inattention	114 (33.2%)	68 (25.3%)	774 (37.3%)
Other	0 (0.0%)	0 (0.0%)	2 (0.1%)
No errors	221 (64.4%)	189 (70.3%)	1077 (51.9%)
TOTAL	343 (100.0%)	269 (100.0%)	2077 (100.0%)
Pedestrian movement			
Alighted from parked vehicle	12 (3.5%)	16 (5.9%)	92 (4.4%)
Crossing with traffic signals	30 (8.7%)	36 (13.4%)	276 (13.3%)
Crossing without control	171 (49.9%)	114 (42.4%)	883 (42.5%)
On pedestrian crossing	16 (4.7%)	10 (3.7%)	68 (3.3%)
Playing on roadway	0 (0.0%)	0 (0.0%)	16 (0.8%)
Pushing or working on vehicle	4 (1.2%)	11 (4.1%)	67 (3.2%)
Walked from between parked vehicles	5 (1.5%)	7 (2.6%)	28 (1.3%)
Walking on footpath	59 (17.2%)	41 (15.2%)	216 (10.4%)
Walking on road	27 (7.9%)	23 (8.6%)	306 (14.7%)
Walking on road – against the traffic	3 (0.9%)	1 (0.4%)	14 (0.7%)
Within 30 m of pedestrian crossing	5 (1.5%)	3 (1.1%)	15 (0.7%)
Other (e.g., police on traffic control)	11 (3.2%)	7 (2.6%)	96 (4.6%)
TOTAL	343 (100.0%)	269 (100.0%)	2077 (100.0%)
Day of week			
Sunday	20 (5.8%)	20 (7.4%)	246 (11.8%)
Monday	48 (14.0%)	39 (14.5%)	305 (14.7%)
Tuesday	49 (14.3%)	41 (15.2%)	282 (13.6%)
Wednesday	48 (14.0%)	50 (18.6%)	301 (14.5%)
Thursday	59 (17.2%)	31 (11.5%)	309 (14.9%)
Friday	78 (22.7%)	54 (20.1%)	336 (16.2%)
Saturday	41 (12.0%)	34 (12.6%)	298 (14.3%)
TOTAL	343 (100.0%)	269 (100.0%)	2077 (100.0%)
Time of day			
00:00 to 05:59	1 (0.3%)	7 (2.6%)	243 (11.7%)
06:00 to 11:59	153 (44.6%)	109 (40.5%)	473 (22.8%)
12:00 to 17:59	148 (43.1%)	104 (38.7%)	723 (34.8%)
18:00 to 23:59	41 (12.0%)	49 (18.2%)	638 (30.7%)
TOTAL	343 (100.0%)	269 (100.0%)	2077 (100.0%)
Speed limit			
10	2 (0.6%)	2 (0.7%)	10 (0.5%)
15	0 (0.0%)	1 (0.4%)	1 (>0.1%)
20	1 (0.3%)	2 (0.7%)	10 (0.5%)
25	2 (0.6%)	1 (0.4%)	20 (1.0%)
40	9 (2.6%)	7 (2.6%)	52 (2.5%)
50	151 (44.0%)	139 (51.7%)	1034 (49.8%)
60	171 (49.9%)	108 (40.1%)	800 (38.5%)
70	2 (0.6%)	0 (0.0%)	30 (1.4%)

	75 and over	65 to 74	18 to 64
80	3 (0.9%)	3 (1.1%)	68 (3.3%)
90	1 (0.3%)	0 (0.0%)	8 (0.4%)
100	0 (0.0%)	3 (1.1%)	23 (1.1%)
110	1 (0.3%)	3 (1.1%)	21 (1.0%)
TOTAL	343 (100.0%)	269 (100.0%)	2077 (100.0%)
Lighting conditions			
Daylight	300 (87.5%)	207 (77.0%)	1206 (58.1%)
Night	43 (12.5%)	62 (23.0%)	871 (41.9%)
TOTAL	343 (100.0%)	269 (100.0%)	2077 (100.0%)

Table 2. Length of hospitalisation for seriously injured pedestrians from three age groups

Number of days	75 and over	% of included	65 to 74	% of included	18 to 64	% of included
< 1	5	10.0	8	19.5	56	22.5
1-5	16	32.0	11	26.8	92	36.9
6-10	6	12.0	4	9.8	38	15.3
> 10	23	46.0	18	43.9	63	25.3
Total included cases	50	100.0	41	100.0	249	100.0
Excluded cases[a]	4		3		13	
Total of all cases	54		44		262	

[a] Cases in which the pedestrian died after a period of hospitalisation were excluded

mon injured regions for all three groups were the chest, followed by the abdomen and, finally, the face.

Discussion

This study involved an examination of the number of older pedestrians hit by motor vehicles in South Australia, the characteristics of their crashes and their injury outcomes, with comparisons made to younger adult pedestrians hit by vehicles. The key findings are discussed in the following sections.

Overall crash involvement

Fewer older pedestrians were hit by motor vehicles in SA between 2008 and 2017 than younger adult pedestrians. However, older pedestrians had higher rates of being seriously or fatally injured and those aged 75 and over had higher rates of being hit per 100,000 population.

The increased risk of serious or fatal injury for older pedestrians compared to younger adult pedestrians corresponds with other research (Baldock et al., 2016; Martin et al., 2010; Oxley, 2009) and is most likely related to fragility, with older adults having a lower tolerance of physical trauma (Evans, 1988; Viano et al., 1989). The reason for the increased crash involvement of pedestrians aged 75 and over per population, however, is not clear. It may be related to declines in their health or cognitive and functional abilities, and the effect that these declines have on their ability to safely negotiate the road environment. Indeed, they are likely to walk at a slower speed than younger pedestrians, which would increase their exposure to traffic and their risk of a crash (Tarawneh, 2001). There was no evidence to demonstrate the effect of health or functional decline or co-morbidities in the current study, so further research is required. It is likely that their fragility, at least partly, would cause their increased crash involvement per population. They would be more likely to sustain injury from lower impact collisions with vehicles, so a larger share of their collisions would be reported to police. Overall, these findings demonstrate that older pedestrians are a vulnerable road user group.

Crash characteristics

Despite having an increased risk of being hit and being seriously or fatally injured, a positive finding is that older pedestrians are not a risk-taking road user group. They were less likely than younger adult pedestrians to be responsible for their crashes and were also less likely to have consumed alcohol, to not be paying attention, to be walking on the road, and to be walking at night (when pedestrian visibility would be reduced) when hit by a motor vehicle.

That older pedestrians were more likely to be hit on Fridays than younger adult pedestrians, who were more likely to be hit on Sundays, would likely reflect the times at which pedestrians of different ages choose to walk. Younger adults work during the day, Monday to Friday, and may undertake a larger share of their walking-based activities on weekends and during night-time hours. In comparison, many

Table 3. MAIS for each body region for seriously injured pedestrians from three age groups, 2014 to 2017

MAIS	Abdomen	Chest	External	Extremities	Face	Head
Age 75 and over						
1	-	-	21	-	2	-
2	3	2	1	7	1	9
3	2	3	-	3	-	5
4	-	1	-	-	-	-
5	-	-	-	-	-	4
Total	5	6	22	10	3	18
Age 65 to 74						
1	-	1	17	-	-	2
2	2	4	-	10	1	4
3	-	2	-	6	-	4
4	-	-	-	-	-	1
5	-	-	-	-	-	-
Total	2	7	17	16	1	11
Age 18 to 64						
1	2	-	71	1	4	6
2	9	13	1	43	10	23
3	4	11	1	12	-	13
4	1	3	-	1	-	2
5	-	3	-	-	-	2
6	-	-	-	-	-	1
Total	16	30	73	57	14	47

older adults would be retired and have more freedom to choose when they walk, particularly during the working week. This is consistent with research in Melbourne, Australia, by Pour, Moridpour, Tay and Rajabifard (2018), which found that vehicle-pedestrian crashes among pedestrians aged over 65 occur more often during daytime off-peak traffic periods (10 am to 3 pm) and on weekdays.

Almost half of the sample of pedestrians (across all three age groups) were crossing the road without protection (traffic signals or a pedestrian crossing) when hit, and the most common error made by these pedestrians was inattention. Not only are these pedestrians crossing without protection, but they are also not paying attention to the road when they cross. Research on pedestrian-motor vehicle crashes in New Zealand by Hirsch, Mackie and McAuley (2021) also found that distraction or inattention was the most common pedestrian-implicated factor (37% of all crashes). The present study found that most pedestrians were hit in areas with speed limits of 50 and 60 km/h. This is likely due to the increased pedestrian activity and vehicle traffic in urban areas compared to rural areas (Prato et al., 2012; Zegeer & Bushell, 2010). Hirsch et al. (2021) found that 80% of pedestrian crashes occurred in urban environments of New Zealand.

Older pedestrians were more commonly walking on the footpath when hit compared to younger adult pedestrians. The researchers noted, when reading police descriptions of several crashes, that older pedestrians often seemed to be walking past driveways when hit by reversing cars or directing their partner/acquaintance who was reversing or manoeuvring a vehicle. This could relate to their slower walking speeds and ability to avoid reversing vehicles.

Injury patterns and severity

As mentioned earlier, older pedestrians have a higher risk of serious or fatal injury when hit by a vehicle. It was also demonstrated that they take longer to recover from serious injuries (the initial severity of their injuries did not differ from younger adult pedestrians, but they were more likely to spend ten days or longer in hospital). The body regions that they most commonly injure, however, were the same as those of younger adult pedestrians, namely external regions, the extremities, and the head/neck. These would be the areas most exposed to collisions with vehicles and then subsequent falls to the ground/road.

Detailed information about the vehicles that hit the pedestrians was not available in the data (other than standard categories such as car, truck, bus, etc.). Therefore, it was not possible to examine whether differences in vehicle aggressivity would affect pedestrian injury outcomes (particularly older pedestrians). Future research could examine this issue.

Potential countermeasures to improve pedestrian safety

Improving the safety of older pedestrians is a difficult problem. It is ideal for their health and wellbeing to continue walking for as long as possible, particularly those who must reduce or cease their driving. Walking should not be deterred for older adults. Elvik (2009) has also demonstrated a "safety in numbers effect", in which the risks of injury to pedestrians are highly non-linear – the more pedestrians there are, the lower is the risk faced by each pedestrian. This would apply to older pedestrians. However, whenever older pedestrians negotiate the road environment, they are exposed to potential collisions with motor vehicles and to a greater degree of potential injury than younger adult pedestrians.

In terms of reducing their crash involvement, a greater balance between the needs of pedestrians and those of vehicles should be achieved in the design and implementation of road infrastructure and the built environment in many inner metropolitan areas, where, arguably, the balance currently favours vehicle movement (Gårder, 2004). A larger number of pedestrian-protected crossings, such as signalised or zebra crossings, could be provided and fencing on the sides of roads that are difficult for pedestrians to cross (i.e., multiple lanes with large traffic volume) would encourage pedestrians to use designated crossings. Alternative barriers (e.g., trees, hedges, raised gardens and outdoor seating) produce the same effect but are more subtle and blend into the roadside aesthetics (Oxley et al., 2004).

Hirsch et al. (2021) demonstrated that drivers failed to stop at signalised crossings and flat zebra crossings in 13% of serious injury and 12% of fatal pedestrian crashes in New Zealand. Therefore, raised zebra crossings (i.e., vertical deflection) with warning signage would be ideal because they slow motorists. This would reduce the risk of serious or fatal injury as previous studies have shown that the higher the vehicle speed on impact, the more severe the outcome for the pedestrian (Anderson et al., 1997; Desapriya et al., 2011; Jurewicz et al., 2017; Kröyer, 2015; Zegeer & Bushell, 2010). Perceptual countermeasures, such as road markings on the approach to pedestrian crossings and in areas with high pedestrian activity that indicate to motorists that they must reduce their speed, are also important to reduce the number and severity of pedestrian-vehicle collisions.

Controlling vehicle speeds to a survivable level, through reduced speed limits and associated enforcement, is very important, particularly in metropolitan areas with high pedestrian activity. Hirsch et al. (2021) suggested that pedestrians are less likely to survive impacts over 30 km/h. This should be considered by authorities when setting speed limits. Slower vehicle speeds also improve the predictability of vehicles for pedestrians crossing the road and the control, manoeuvrability, and reaction and braking distance for drivers, thereby reducing the risk of collision (Oxley et al., 2004).

Zebra crossings are also ideal because they allow older pedestrians to cross at their own pace, without the constraints and pressure of designated crossing times provided by signalised intersections. Pedestrian over/underpasses protect pedestrians, including those who are distracted, by removing them from the road environment, but are expensive and often difficult for older persons (walking up/down stairs or ramps). Vehicle over/underpasses are also expensive but at least eliminate any additional difficulty for pedestrians. Wider footpaths with good visibility for both drivers and pedestrians may reduce the risk to older pedestrians on footpaths. Vehicle-free zones prioritise pedestrian movement and effectively remove the risk of vehicular collision.

Vehicle design can affect injury outcomes for pedestrians. Energy-absorbing vehicle components, located on the bonnet and front of vehicles, can minimise injury severity (Crandall et al., 2002). Testing of the pedestrian protection afforded by vehicles and incorporating the results into overall vehicle safety ratings has encouraged improvements in vehicle design (Ponte et al., 2013). However, even greater improvements for the protection of older pedestrians could be achieved if testing was tailored to account for the fragility of older adults rather than a one-size-fits-all standard. The implementation of certain technologies in vehicles is also important for pedestrian safety, including Autonomous Emergency Braking, reversing cameras, rear collision warnings, pedestrian frontal collision warnings and intelligent speed assistance, all of which will become more common as the vehicle fleet is upgraded. However, some vehicle modifications can have adverse safety effects. For example, Anderson, van den Berg, Ponte, Streeter and McLean (2006) demonstrated that metal bull bars increase the risk of severe injury or death to a pedestrian in a crash.

Study Limitations

There were limitations related to the police-reported crash data. Non-injury crashes and near-misses would not be included (Hirsch et al., 2021). This will bias the results towards a greater representation of crashes that resulted in injury.

Also, the proportion of pedestrians for whom BAC was reported was low in both the police-reported (22%) and hospital admissions data (63%). This could bias the results related to alcohol consumption by crash-involved pedestrians. These low rates of testing and reporting need to improve to provide a better understanding of the role of alcohol in pedestrian-vehicle collisions. In comparison, BAC testing of vehicle occupants is mandatory and, as a result, the rates are high.

Conclusions

Older pedestrians are a growing road user group due to the large baby boomer generation (born 1946-1964) moving into the older age bracket and current older adults living longer, healthier, and more active lives than earlier cohorts. The present study has highlighted that they are also a particularly vulnerable group. This study provides data-based rationale for implementation of pedestrian safety countermeasure recommended in this paper.

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Author Contributions

James Thompson contributed to this research through: design, methodology, data analysis, execution, and interpretation of the reported study; and draft preparation and revision of the article.

Matthew Baldock contributed to this research through: conceptualisation, funding acquisition, design, methodology, and project administration of the reported study; and revision and editing of the article.

Both authors have read and agreed to the published version of the manuscript.

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Human Research Ethics Review

The data collection undertaken for this project was approved by the Central Adelaide Local Health Network Human Research Ethics Committee (HREC/14/RAH/356).

Conflicts of interest

The authors declare that there is no conflict of interest.

Data Availability Statement

All of the data used for this project were made available solely for the use of CASR researchers and much of the data are very sensitive in nature. Under the terms of our ethics approval, CASR cannot make the data available to others.

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