

# THE IMPORTANCE OF AGE FOR INJURY SEVERITY AMONG CAR DRIVERS AND PEDESTRIANS

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## ABSTRACT

The risk of injury is known to be related to age. The elderly population has a far higher risk of both serious injury and fatality, for a given severity of impact. While this is known, it is not always used for the understanding of the options for injury prevention that is available or could be developed. In the present study, the risk of in particular pedestrian injuries and fatalities were related to age. It was found, that the risk for older pedestrians is far higher than for younger, risk ratios of over 10 for the oldest age group were recorded. At the same time, the majority of fatalities for pedestrians in Sweden occurred in 50 km/h zones.

In conclusion, the combination of the very high risks for elderly pedestrians and the occurrence of many of the deaths in speed zones of 50 km/h indicate that prevention techniques related to the vehicle would be very effective. Such techniques are both more friendly fronts of cars as well as emergency braking systems. At the same time, modifications to the speed management might be very useful since small changes of impact energy changes the risk of fatality substantially.

## INTRODUCTION

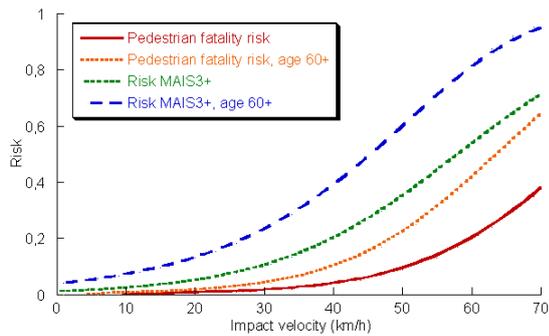
Age has been known to be an important factor in traffic safety, in particular regarding risk of injury for a given amount of mechanical force. Older persons have a higher risk of injury, and it is known that this risk accelerate with higher age. Also the risk of death is higher as well as the risk of long-term consequences (Stigson and Kullgen 2010,

Henary et al 2006, Sunnevång et al 2009, Hanrahan et al 2009).

The importance of age is growing, not only because of a larger population that is older and active in the road transport system, but also because injury prevention and mitigation can and will be more tailored towards elimination of all serious injuries. In doing so, it is likely that system requirements must be based on the older population, being the most fragile part. A better understanding of specific properties of an elderly population will be needed.

Risk functions, linking the amount of energy to risk of injury, are a necessary tools when designing safety systems, and in particular elimination or optimizing to minimize serious injury. Risk functions are mostly related to the average population, while today it is rarer to develop specific risk functions for the elderly population.

Stigson and Kullgren (2010) estimated the risk of injury and the risk of fatality for different impact velocities for the entire pedestrian population and for elderly pedestrians (Figure 1). This study was based on several earlier studies, mostly with data from reconstructions of accidents. It is clear from this study that the risk of injury and fatality is larger for the older population, but it seems that the difference is more important for higher impact velocities. This should though be put in perspective that most accidents with pedestrians involved occur in built up areas, with lower driving speed. For a holistic analysis both risk functions and exposure functions (number of impacts to impact speed) are needed.



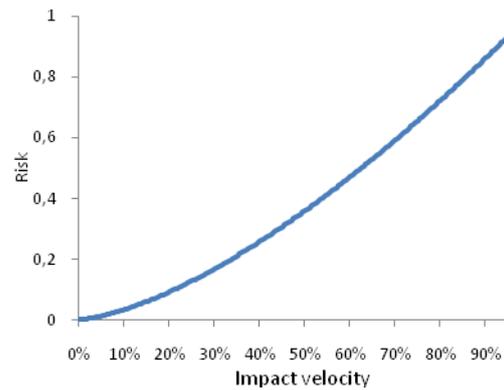
**Figure 1. The risk of injury MAIS 3+, and fatality, related to impact velocity, for different age groups. From Stigson and Kullgren 2010.**

The aim of the present study was to show the importance of age for the risk of serious injury and fatality for car drivers and pedestrians in particular.

### METHODS AND MATERIAL

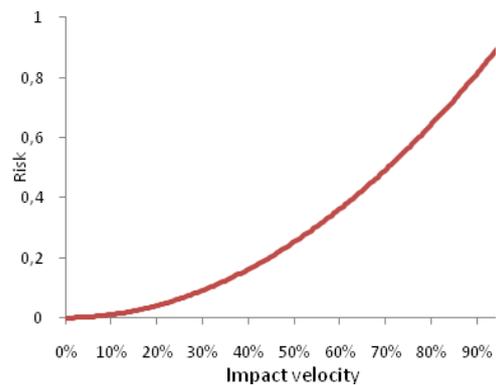
The data used in the study is in essence police reported road crashes with injury. Such data is known to have serious underreporting and misclassification. Both these problems are relevant in the analysis. The underreporting leads to that no estimates on nominal risks can be generated, and the misclassification between slight and serious injury leads to that some of the ratios cannot be seen as good estimates. As the study is more related to relative relations, the consequences of the quality deficiencies are limited. Data from Sweden was used as well as a dataset from Germany (BAST). The Swedish was from 2003 to 2010. The German data is from 2003-2008. The factors used in this study were age, speed limit and type of road user.

A risk function is the link between crash severity and injury. In this analysis risks are described as power functions. The theoretical background to the risk functions is partly based on the family of power functions, describing the relationship between speed and injury as a set of power functions with power from 1 to more than 4 depending on the severity of injury (Nilsson 2000, Elvik 2009). In this paper, an extension of this theory and empirical values chosen was used, where the ratios of the severity of injuries were assumed to be the ratio of the power functions. According to Elvik (2009), the power for fatalities is around 4.5, while the power for serious injury is around 3. The ratio would in that case be 1.5 theoretically (Figure 2).



**Figure 2. The relationship between impact speed and the ratio fatal to fatal and seriously injured (F/FS) with power 1.5.**

Some analyses (Elvik 2009) would suggest that the relation for fatal to fatal and serious injury in urban areas would be between 1.5 and 2 (Figure 3). These relationships were used in the present study to explain the non-linear relationship between speed and the ratio between fatalities and the sum of fatalities and serious injuries.

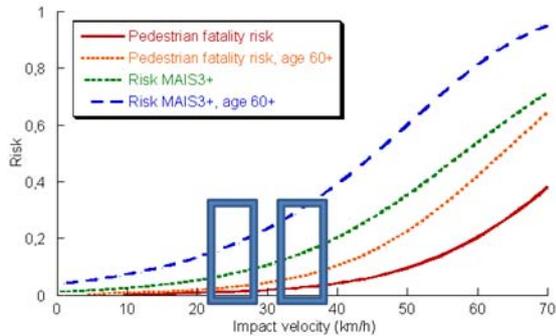


**Figure 3. The relationship between impact speed and the ratio fatal to fatal and seriously injured (F/FS) with power 2.**

In Figure 2 and 3, 100 % represent the impact velocity where the risk of a fatality is 100 %. A ratio between fatalities and the sum of fatalities and seriously injured of, say, 40 %, would for a power of 1.5 represent that the impact velocity is around 50 % of where the risk of a fatality is 100 % (everyone is killed). With a power of 2 it would represent approximately 60 %.

## RESULTS

In Figure 4, based on Figure 1 from Stigson and Kullgren (2010), two hypothetical areas are identified. The left area would then represent low severity impacts with pedestrian, typically in a 50 km/h zone. The right area represents a higher impact velocity, typically in a 70 km/h zone.



**Figure 4. The risk of injury MAIS 3+, and fatality, related to impact velocity, and two separate impact severity segments. Modified from Stigson and Kullgren (2010).**

From the relations shown in Figure 4, several relations can be formed. The ratio between the number of fatal to serious and fatal injuries is one relation. This relation can also be related to different age groups. At a lower impact severity, the proportion of fatalities to serious injuries should be low, and by higher impact severity grow, and at some point, reach 1. In table 1, the number of fatally, seriously and slightly injured pedestrians of different ages, are shown.

**Table 1. The number of fatally, seriously and slightly injured pedestrians of different age, where the speed limit is 50 km/h. Sweden**

	Fatal	Serious	Slight	All
0-44	38	1026	3496	4560
45-64	35	366	1001	1402
65+	145	566	915	1626

It can be seen that the profile of fatal, serious and slight injuries differs substantially by age. While the ratio fatal to all injuries for 0-44 years of age is below 1 %, the corresponding ratio for 65+ is almost 10 %. The ratio fatal to fatal and seriously injured is 4 % for the youngest, and almost 24 % for the oldest age group (table 3). All these results imply that while the risk functions for younger versus older pedestrians might have the same

overall relationship between impact velocity and risk they display very different levels also at low speed. In the present data set, from Sweden, more than half of the fatalities occur in speed zones up to 50 km/h.

Table 2 shows the same results, but for speed zone 70 km/h. It can be seen, that the ratios between fatalities and all injuries as well as fatalities to fatal and serious injuries is far higher than for the 50 km/h speed zone. For the youngest group, the ratio between fatalities and all injuries is almost 10 %, while for the oldest group it is now 25 %. The fatal to fatal and serious injury is 16 and 43 % (table 3). The latter figure shows that serious injury is at the tipping point for the decline of the serious injury risk, where fatalities are the only group where the risk increases.

**Table 2. The number of fatally, seriously and slightly injured pedestrians of different age, where the speed limit is 70 km/h. Sweden**

Age	Fatal	Serious	Slight	All
0-44	32	171	197	400
45-64	15	48	68	131
65+	25	33	46	104

**Table 3. The percentage of fatalities to fatalities and serious injured (F/FS) for 50 and 70 km/h speed zone. Sweden**

Age	F/FS 50 km/h	F/FS 70 km/h
0-44	3,6	15,7
45-64	8,7	23,8
65+	23,7	43,1

In summary, the difference in risk, as expressed by the number of fatalities in relation to either all injuries or to fatal and serious injuries shows, that the risk ratios for older to younger pedestrians is 10 times and 5 times higher, respectively. This is at the same time the most common speed zone representing these cases, in Sweden typically around 50 %. At the higher speed zone, the corresponding risk ratios are 2 to 3 times. This is still a substantial difference, but represents a smaller risk population.

German data show a similar scenario, with a high increase of fatal to fatal and serious ratio. The German data can be subdivided for the eldest group, showing that the largest increase is for the age

group over 75 years. The differences are somewhat smaller for the German data, but in general it can be seen that in 50 km/h zone, the relationship between age and injury severity is similar to the relationship based on Swedish data.

**Table 4. The percentage of fatalities to fatalities and serious injured (F/FS) for 50 and 70 km/h speed zone. Germany**

Age	F/FS 50 km/h	F/FS 70 km/h
15-44	3,2	23,6
45-64	9,3	32,0
65-74	9,1	29,3
75+	16,6	33,7

For car occupants, speed zone 50 km/h is used as a reference to pedestrians. In Table 5, the number of fatalities, serious injured and slight injured can be seen.

**Table 5. The number of fatally, seriously and slightly injured car drivers of different age, where the speed limit is 50 km/h. Sweden**

	Fatal	Serious	Slight	All
0-44	121	2636	26621	29258
45-64	56	1114	11069	12239
65+	73	552	3682	4307

Given the same amount of underreporting of injuries, in particular slight injuries, and the likely effect of that the number of uninjured, it is clear that the risk of injury or fatality is only a fraction of the risk of injury to pedestrians in the same type of environment. The ratio fatal to fatal and serious injury is though more relevant, showing a similar development by age, where for the older group the ratio is three times higher than for the younger age group.

## DISCUSSION

The influence of age on injury risk and injury severity is well known and validated in many different ways. The implications of these findings have also been discussed for a long time (Evans). Regarding pedestrians, it is, however, not clear how these facts are translated into practice when integrated safety is developed. In doing so, risk functions, vehicle design, speed management and vehicle based autonomous systems like emergency

braking should be brought together to form a system that is safe for pedestrians.

Speed and speed at impact has a major influence on injury, and has been demonstrated with many methods (Nilsson 2000, Stigson and Kullgren 2010, Liu et al 2002, Evans 1991). Risk functions, linking speed to injury risk through mathematical functions, is a well known technique, but the methods to measure or reconstruct impact speed are sometimes exposed to errors or poor accuracy. In particular impact velocity in when pedestrians are hit by a car is complicated. Several attempts have been made to generate such functions, but still with major problems (Stigson and Kullgren).

To generate risk functions on the basis of police reported data is not easy. Underreporting and misclassification of injuries are major sources for low quality, and the absence of speed at impact is also creating problems. On the other hand, there might be well-founded relations between fatal and serious injuries that can be used to understand relative risks associated with speed and speed at impact. While this study does develop such relationships, the ratios fatal to fatal and seriously injured are used to demonstrate the influence of age. If this relation were a power function with power 2, a 20 % proportion of fatalities would indicate that the mean impact velocity in a 50 km/h zone is almost 50 % of the level where the risk of a fatality is 100 %. While the mean impact speed in a 50 km/h speed zone is lower than the maximum posted speed limit, the current study cannot generate the actual or true average impact speed. If the mean impact speed would be, say, 30 km/h, it would mean that the 100% death risk would occur between 60 and 70 km/h. for the old population. It is still, though, to be further studied if these relations are valid, and what function that best describes the relationship. It is still clear, that the ratio is a measure of impact severity and risk of injury.

The results of the present study show, that the elderly pedestrians have a much higher risk of serious and fatal injury than the rest of the population. In the present study elderly is defined above 65 years age. The German data indicates an even higher vulnerability of pedestrians above 75 years age.

The figures from Sweden also show that the majority of pedestrian fatalities occur at 50 km/h speed zones. This opens up for that lowering the impact velocity in those zones would be very beneficial. This is in contrast with the view that the risk level at low speed is very low for pedestrians, and that the main effects would occur as a result of treating higher speed levels. While the present study cannot generate true risk functions, it is clear that a common risk function for all ages is not relevant. Such a starting point would probably lead to a serious underestimate of interventions that are directed to moderate speed reductions or improvements of friendly vehicle fronts. On the contrary, the findings indicate that such interventions would be highly beneficial in an environment that supports low speeds in areas where pedestrians are exposed to traffic. In the present study, the indication is that lowering the risk of serious injury and fatality in 50 km/h zones would be very beneficial, with the help of things like autonomous emergency braking and more friendly front design (Strandroth et al 2011, Fredriksson and Rosén 2010). This is not the case with pedestrian crashes at high speeds. In such areas it is possibly more beneficial to separate pedestrians from traffic. For non-separated areas, the speed limit should probably be 30 or 40 km/h to allow a safety margin for vehicle mitigation and protective systems to be effective for the elderly population with low tolerance to crash forces.

## CONCLUSIONS

- The risk of injury for in particular pedestrians are at least ten times higher for elderly (65+ years) than those aged 0-44 years in speed zone 50 km/h
- The vast majority of fatal pedestrian crashes occurred at 50 km/h speed zones.
- The scope for a combination of vehicle safety and speed management should be effective in eliminating death and serious injury to elderly pedestrians.
- The risk of serious injury to car occupants is also related to age.

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