Developments in car crash safety since the 1980s

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Abstract This study aimed to evaluate developments in car crash safety in cars launched since the 1980s based on real-world crashes occurring years 2000–2019, with focus on the number of injuries leading to permanent medical impairment to different body regions, separated for gender and age. Police-reported two-car crashes were used to calculate relative risk of any injury, fatal and serious injury and fatality, and together with occupant injuries reported by Swedish emergency care centres the risk for permanent medical impairment was assessed. The cars were categorised in ten-year periods according to year of introduction.

It was found that vehicle crashworthiness has improved steadily since the 1980s, with largest improvements for serious and fatal injuries and for injuries leading to PMI. Females were found to have higher injury risk for all types of injury severity studied (except for fatal injuries). The risk for serious and fatal injuries and fatal injuries alone was higher for occupants older than 50 years of age compared to those younger than 50. For male occupants, as well as for occupants younger than 50 years, the risk for injury leading to PMI to the cervical spine was found to increase in modern cars. Older occupants were also found to have an increased risk for injuries to the thoracic and lumbar spine.

Keywords Age, crashworthiness, gender, permanent medical impairment, safety development.

I. INTRODUCTION

Previous studies based on real-world crashes have shown positive developments with regard to crash safety performance over the last 40 years [1-4]. Both fatality risk and risk of serious injury have been reduced. Risk for minor injuries has dropped, but not to the same extent as risk for more serious injuries [1]. A positive development has also been shown for injuries with high risk of permanent medical impairment (PMI) [1].

In 1997, the Swedish parliament implemented the Vision Zero strategy, with a long-term goal of no fatal or serious injuries within the road transport system [5]. The definition of a serious injury in the Swedish strategy is an injury leading to PMI [6]. This lent a greater focus to fatal injuries and injuries leading to PMI. It is important, therefore, to follow the improvements in the passenger car fleet with respect to injury outcome in terms of both fatality and injuries leading to PMI. Large variations in risk for PMI depending on injured body region and AIS level have been shown [6,7], along with differences in risk for different age groups and by gender [6,8]. However, studies showing developments in car crash safety with regard to risk for PMI for different injury types and body regions are rare.

Several international institutions have published vehicle safety ratings based on retrospective statistical analyses of real-world crash databases, such as Transport Research Laboratory in the UK, Highway Loss Data Institute in the USA, Used Car Safety Ratings in Australia, Traffic Safety Committee of Insurance Companies in Finland, and the Folksam Insurance Group in Sweden. Folksam has regularly published car safety ratings since 1983. The Folksam system rates the relative risk of a driver sustaining an injury that leads to fatality or PMI, across all impact directions and locations [2,9,10].

Consumer tests published around the globe are influencing the development of car safety, and studies have shown a correlation between Euro NCAP results and injury risk based on real-world crashes [1,11]. In these studies, police assessments of injury outcome (killed, seriously injured, minor injuries or uninjured) were used as the injury descriptors. Studies have also shown that the risk for injuries leading to PMI also correlates with the Euro NCAP results [1]. Five-star rated cars were shown to have approximately 40% lower risk for both fatal injuries

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and injuries leading to PMI compared to two-star rated cars.

This study aimed to evaluate developments in car crash safety in cars launched since the 1980s based on real-world crashes occurring years 2000–2019, with special focus on the development of injuries leading to PMI to different body regions. An additional aim is to evaluate developments in injury risk separated for gender and age.

II. METHODS

The data consisted of two-car crashes reported by the police during accident years 2000–2019 (n=177,234) and front-seat occupant injuries reported by emergency care centres during accident years 2003–2019 (144,521 diagnoses for 55,597 occupants) to the Swedish Traffic Accident Data Acquisition database (STRADA). Police-reported crashes were used to calculate relative risk of any injury, serious injury and fatality. Injury diagnoses coded according to AIS 2005 [12] were used to calculate risk for PMI [6]. Developments were studied in terms of risk of any injury, risk of serious injury, risk of PMI and risk of fatality. The body regions were categorised according to the definitions in AIS [12], except for the region spine, which was further divided into cervical, thoracic and lumbar spine [6]. Occupants reported to be unbelted were excluded in the analyses.

To mirror the developments in crash safety, the car models were categorised in 10-year periods according to year of introduction, beginning in 1980–89 and ending in 2010–2019. The year of introduction was chosen to describe the year of design. The developments were analysed for gender and age groups, below and above 50 years age. The following sections describe how the relative risk, using paired comparisons and the risk for PMI, was calculated.

Calculating the Relative Injury Risk using Police Data

Relative injury risks were calculated using the pair comparison technique for two-car crashes. The method was initially developed by Evans [13], but has been further developed by Folksam for car-to-car collisions [2,9,10]. The relative injury risk for a specific group of cars was calculated by comparing the number of crashes with injured drivers for that group with the number of crashes with injured drivers for the cars with which they collided. All car-to-car crashes were included irrespective of crash type. It was assumed that for a specific crash severity, the injuries among occupants in one car are independent of the injuries among occupants in the other car. By studying two-car crashes the pair comparison method controls for variation in impact severity, apart from the influence of car mass.

When using this method some factors will influence the outcome and their influence need to be adjusted for. In two-car crashes, mass differences will influence the measured relative injury risk because they alter the impact severity distribution between the groups. This influence can be adjusted for in the model, and it is further described below how this has been done. Another factor potentially influencing the results is aggressivity, defined as the properties of a vehicle other than the mass that can influence the risk of injury to the occupants of other vehicles (its structure and stiffness, for instance, can have such an effect). However, for passenger cars the influence of aggressivity on injury risk in paired comparisons has been shown to be much smaller (70–75%) than the influence of mass [10,14]. The difference in aggressivity for the groups of cars studied (10-year periods according to year of launch) is assumed to be small as there is a similar mix of cars in all 10-year periods, thus aggressivity was not adjusted for in this analysis. When using an accident sample including accidents during a 20-year period, car models launched early in this period will in average be colliding with an older car compared with cars launched late in this period. A description of how this is adjusted for is further described below.

Using the pair comparison method, crash outcomes in two-car crashes were grouped in four groups (see Table I), where x_1 is the number of crashes with injuries to drivers in both cars, x_2 is the number of crashes with injuries in the case car (Car 1) only but not in the other vehicle (Car 2), x_3 is the number of crashes with injured drivers in the other car but not in the case car, x_4 reflects the situation where no one was injured in the crash (often little data are available here). In calculating the relative risk, x_4 is not used because it does not add any important information for the relative injury risk.

TABLE I
NUMBER OF IMPACTS WITH DIFFERENT COMBINATIONS OF INJURED DRIVERS IN CAR 1 AND CAR 2

		Driver of Car 2		Total
		Driver injured	Driver not injured	
Driver of Car 1	driver injured	x_1	x_2	$x_1 + x_2$
	driver not injured	x_3	x_4	
Total		$x_1 + x_3$		

The unadjusted relative risk between the case car or group of case cars and its collision partners is calculated as the ratio between injuries in the case car compared with the injuries in its collision partners (Equation 1). The collision partners are considered a sample of the whole car population, and therefore provide the exposure basis that allows for comparisons across all case cars or groups of case cars.

$$R=(x_1+x_2)/(x_1+x_3) \quad (1)$$

Compensation for Mass Differences

The influence of mass on injury outcome described by power model functions has been described extensively by Elvik *et al.* [15] and by Krafft *et al*. [16]. If the masses differ between the case vehicles and the vehicles with which they collide, both groups will be exposed to an impact severity different from that arising when the two groups of vehicles have the same mass. If the case vehicle group is lighter than the other vehicle group, it will experience a higher impact severity compared to its collision partners (Impact Energy = mass * velocity^2). At the same time, the other, heavier vehicles will experience a lower impact severity. The mass differential will therefore result in a benefit for one vehicle and a disadvantage for the other vehicle in a two-car crash. To allow for accurate comparisons and adjust for the influence of mass on the outcome for the case vehicles, the altered impact severity distribution for the cars with which they collide must be compensated for in the model. The adjusted relative injury risk is therefore expressed as in Equation 2. The power y in Equation 2 varies depending on the severity of the injury studied. Three mass adjustments were used depending on the injury severity: all injuries y=0.5, fatal and serious injury y=1.8, fatal injury y=3.5 [1,2,15]. The more severe the injury, the higher power 'y', resulting in a steeper slope of the risk curve.

$$R_{mass\ adjusted}=(x_1+x_2)/(x_1+x_3)* M^y \quad (2)$$

where M = (average mass for case vehicles)/(average mass for other vehicles).

Compensation for the Year of the Crash

It has previously been found that the average safety level of vehicles in the fleet increases every year [10]. When using the pair comparison method with an accident sample including accidents that occurred twenty years back in time, car models launched early in this period will in average collide with less safe cars compared to modern cars, which means that their relative risks will be influenced by this difference. By using the paired comparison method, it is possible to calculate the average decrease in injury risk of the whole car fleet. In [10,11] the average decrease in risk was found to be 1.5% per accident year as a linear relationship. For example, a car model involved in collisions 10 years ago experienced an average collision partner that was 15% less safe than the average level today. This means that the rating result for that model will be 15% better than the true result if compared with the average safety level of models existing today. Therefore, based on these results, compensations have been made to adjust for the year of impact according to Equation 3:

$$x_{i,\ adjusted} = \sum_{j=1}^{m} [x_{i,j} * (1 + f*(Year_{actual} - Year_j))] \quad (3)$$

where f = 0.015 (1.5% per year), $Year_{actual}$ = latest accident year in the sample and $Year_j$ = accident year for the particular crash.

The accident year compensation was made for each crash with a factor linked to the accident year. The adjusted relative injury risk was calculated based on the ratio between the adjusted x_1+x_2 in the nominator and the unadjusted x_1+x_3 in the denominator. The final formula used to calculate the relative injury risk from the police data would therefore be:

$$R_{adjusted} = (x_{1,\ adjusted}+x_{2,\ adjusted})/(x_1+x_3) * M^y \quad (5)$$

Calculation of risk of permanent medical impairment

The risk of PMI (RPMI) was used to measure the risk of long-term consequences [6]. The risk of sustaining an injury leading to PMI of at least 1% and 10% according to the procedures used by Swedish insurance companies [17] was chosen. Medical doctors decide the degree of a medical impairment with the help of grading rules [17], rules used by all Swedish insurance companies. Most European countries have similar rules. A final degree of impairment is normally set three years after the collision. The degree of PMI is assessed between 1 and 99% and is regardless of the claimant's profession or hobbies. All injuries were classified according to the 2005 revision of the Abbreviated Injury Scale (AIS) [12]. An impairment risk has been calculated for each AIS level and body region [6], Table II.

TABLE II

RISK OF PERMANENT MEDICAL IMPAIRMENT OF AT LEAST 1% AND 10%, RESPECTIVELY, FOR AIS LEVELS 1 TO 5 (FIGURES IN PERCENT) (FROM MALM *ET AL.* [6]).

Body region PMI>1%	*1*	*2*	*3*	*4*	*5*
Head	8.0	15	50	80	100
Cervical Spine	16.7	61	80	100	100
Face	5.8	28	80	100	n.a.
Upper Extremity	17.4	35	85	100	n.a.
Lower Extremity and Pelvis	17.6	50	60	60	100
Thorax	2.6	4	4	30	30
Thoracic Spine	4.9	45	90	100	100
Abdomen	0.0	2.4	10	20	20
Lumbar Spine	5.7	55	70	100	100
External (Skin) and Thermal Injuries	1.7	20	50	50	100
Body region PMI>10%	*1*	*2*	*3*	*4*	*5*
Head	2.5	8	35	75	100
Cervical Spine	2.5	10	30	100	100
Face	0.4	6	60	60	n.a.
Upper Extremity	0.3	3	15	100	n.a.
Lower Extremity and Pelvis	0.0	3	10	40	100
Thorax	0.0	0	0	15	15
Thoracic Spine	0.0	7	20	100	100
Abdomen	0.0	0.0	5	5	5
Lumbar Spine	0.1	6	6	100	100
External (Skin) and Thermal Injuries	0.03	0.03	50	50	100

Table II shows the probabilities for PMI for different body regions and AIS levels. The RPMI for an occupant is calculated by multiplying the individual risks for each injury diagnosed with the highest AIS level in each body region according to Equation 6, where p_i is the risk of sustaining a PMI from an injury of a certain AIS level to body region i. This is slightly conservative as it doesn't account for multiple injuries to the same body region. Based on all reported injuries for a specific group of cars, an average risk that an injury would lead to a PMI was calculated.

$$RPMI = (1-\Pi\ [1 - p_i])) \quad (6)$$

Calculation of Relative Risk of Permanent Medical Impairment

The overall relative risk of receiving an injury leading to fatality or PMI is then obtained by combining the relative injury risk and injury severity measures (Equation 7). The method has been used in Folksam's car model safety ratings since the 1990s. The latest description of the rating procedure was published by [10]. For the relative risk of PMI 95% confidence intervals (CI) were calculated using Monte Carlo iterations.

$$\text{Relative risk for PMI} = R_{adjusted} * \text{RPMI} \quad (7)$$

In the calculations of relative risk for an injury leading to PMI for a body region, the mean risk of PMI for all injuries to the body region was multiplied by the proportion of all injuries and the relative injury risk for each interval of introduction year for the group of cars. Hence, all risk figures can be directly compared with each other.

III. RESULTS

A larger proportion of occupants were reported to be unbelted in cars launched 1980-89 compared with cars launched 2010-2019, and the proportion of older occupants was lower in older cars, Table III. However, the proportion of males was the same for all groups. Those reported to be unbelted were excluded in the analysis.

TABLE III
PROPORTION OF; OCCUPANTS REPORTED TO BE UNBELTED, OCCUPANTS ABOVE 50 YEARS AGE AND MALE OCCUPANTS.

	Unbelted	*Occupants >50 years*	*Males*
1980-1989	7%	31%	61%
1990-1999	4%	32%	61%
2000-2009	3%	35%	60%
2010-2019	1%	37%	60%

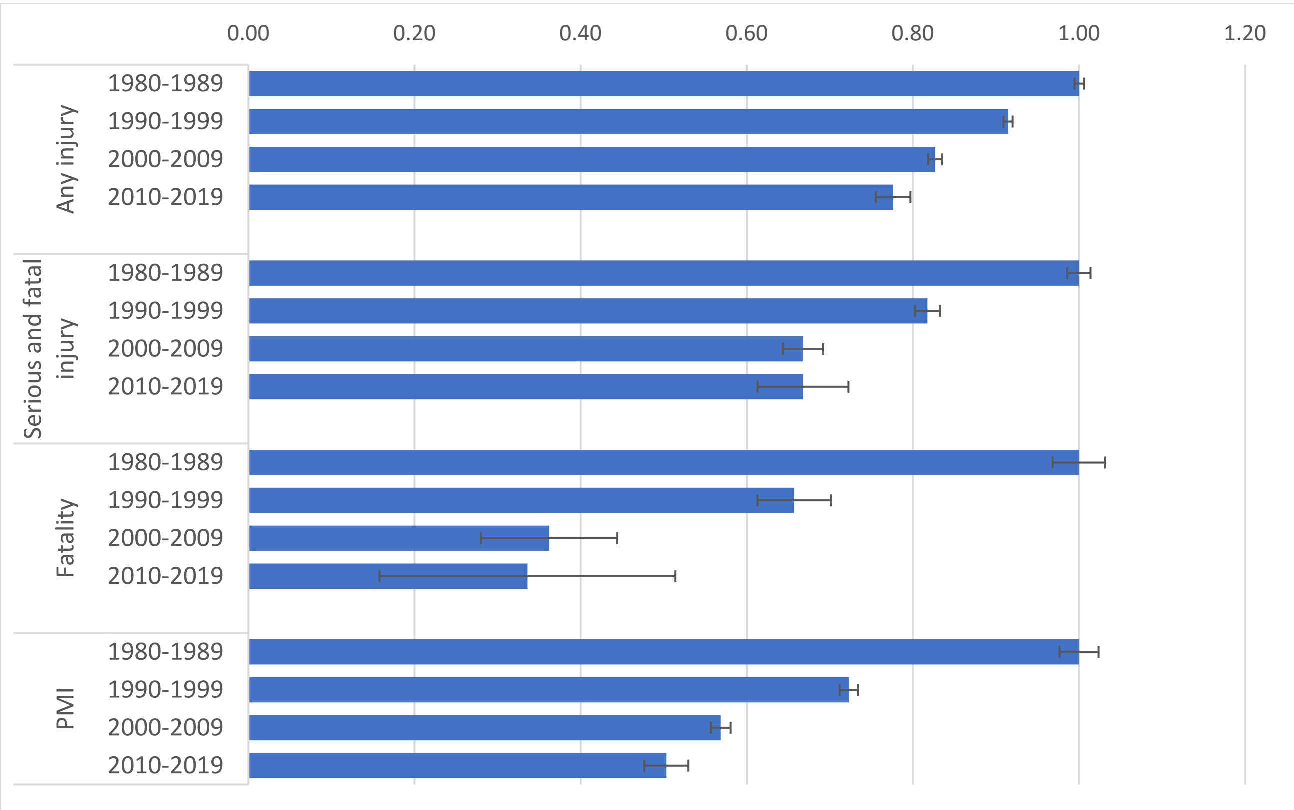

Fig. 1. Development in relative risk for any injury, serious and fatal injury, fatal injury and injuries leading to

PMI>10% for cars launched 1980–89 to 2010–19 (95% CI included).

Vehicle crashworthiness was found to have improved since the 1980s for all injury severity levels studied. Comparing car models introduced in 1980–1989 with models introduced in 2010–2019, it was found that the risk of any injury was reduced by 22% (+/-2%), the risk of serious and fatal injury by 33% (+/-5%), the risk of fatal injury by 66% (+/-17%) and the risk of PMI by 50% (+/-3%) (see Fig. 1 and Appendix). Regarding the risk of fatality, the number of crashes was relatively low for the latest 10-year period, resulting in a wide 95% CI.

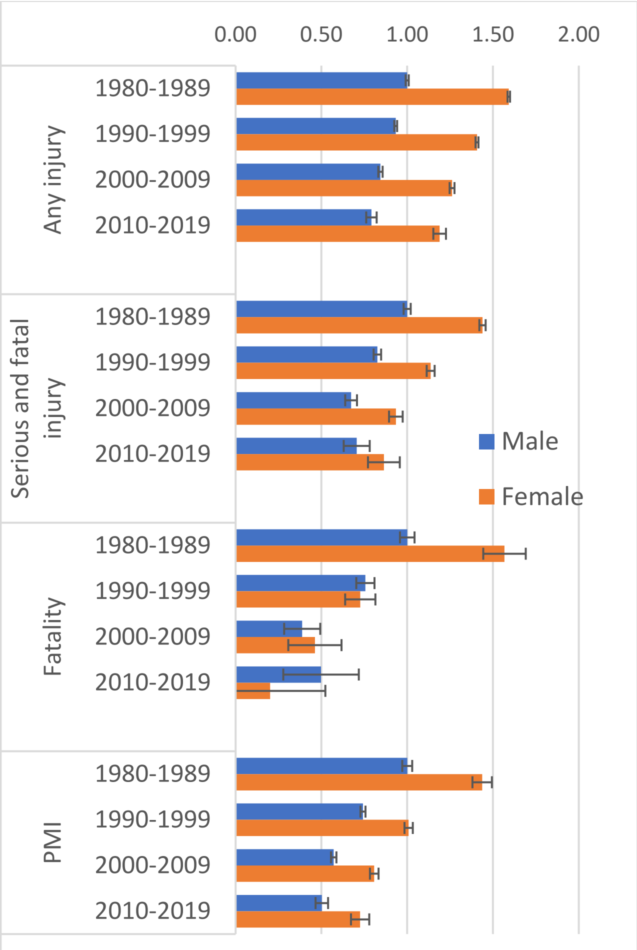

Fig. 2. Development in relative risk for any injury, serious and fatal injury, fatal injury and injuries leading to PMI>10% for cars launched 1980–89 to 2010–19 split for gender (95% CI included).

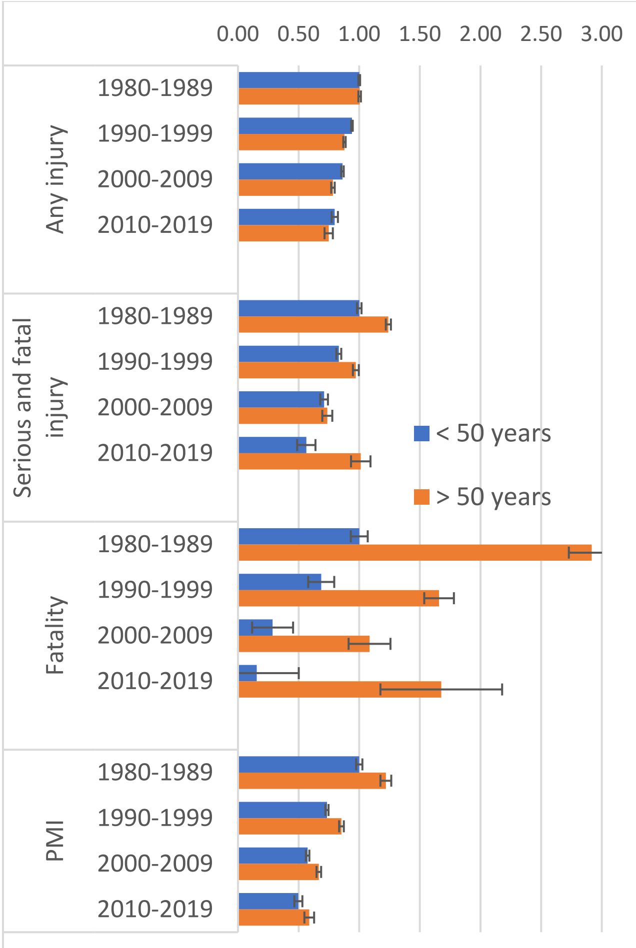

Fig. 3. Development in relative risk for any injury, serious and fatal injury, fatal injury and injuries leading to PMI>10% for cars launched 1980–89 to 2010–19 split for front-seat occupants younger and older than 50 years age (95% CI included).

The injury risks and improvements in risk for the model years of introduction studied were found to differ for males and females and between occupants below and above 50 years of age. For all injury severity parameters studied, except for fatalities, the risk was higher for females, between 44% and 59% higher depending on the injury severity parameter studied (Fig. 2 and Appendix). However, the reduction in risk of more severe injuries seems to be higher for females. Comparing car models introduced in 1980–1989 with models introduced in 2010–2019 (Figs 2 and 3 and Appendix), it was found that the risk of any injury was reduced by 21% (+/-3%) for males and by 25% (+/-2%) for females. For serious and fatal injuries, the corresponding figures were 29% (+/-8%) for males and 40% (+/-6%) for females, and for fatal injuries 50% (+/-22%) for males and 87% (+/-21%) for females, while for injuries leading to PMI the reduction were the same for males and females, 50% (+/-4%).

Occupants older than 50 years had significantly higher risk for fatal injuries compared to those younger than 50 years (Fig. 3 and Appendix). It can also be seen that the fatality risk and risk for serious and fatal injury for occupants above 50 years seem to increase when comparing car models launched 2000–2009 and 2010–2019 (regarding fatality risk the difference is not significant). The reduction in risk for PMI was similar for the two age groups when comparing car models introduced in 1980–1989 with models introduced in 2010–2019: 50% (+/-3%) for occupants below 50 years and 52% (+/-3%) for occupants older than 50 years.

When comparing car models introduced in 1980–1989 with models introduced in 2010–2019, it was found that the reductions in risk of an injury leading to PMI>1% differed depending on body region, gender and age. In general, large improvements were found for injuries to the head, face, thorax, abdomen and lower extremities/pelvis, while no or small improvements were found for injuries to the cervical spine, upper extremities, thoracic spine and lumbar spine (Figs 4 and 5). Injuries to the head leading to PMI>1% were found to drop by approximately 70%, injuries to the face by approximately 60% and injuries to the thorax by approximately 50% for both males and females. For males, the risk of a cervical spine injury leading to PMI was found to increase by 7% when comparing car models introduced in 1980–1989 with models introduced in 2010–2019, while for females the risk decreased by 12%. Another body area where the risk differed was lumbar spine, which increased by 50% for males while no change in risk was seen for females. Injuries to the lower extremities and pelvis was reduced by 48% for males and by 38% for females (Figs 4 and 5).

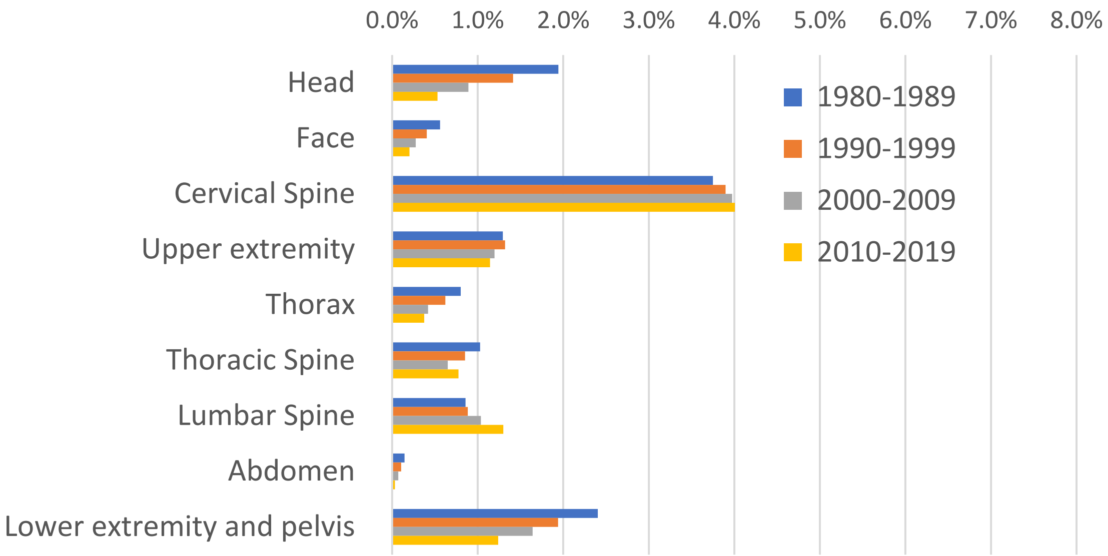

Fig. 4. Development of risk for PMI to different body regions for males for cars launched for the 10-year periods 1980–89 to 2010–19.

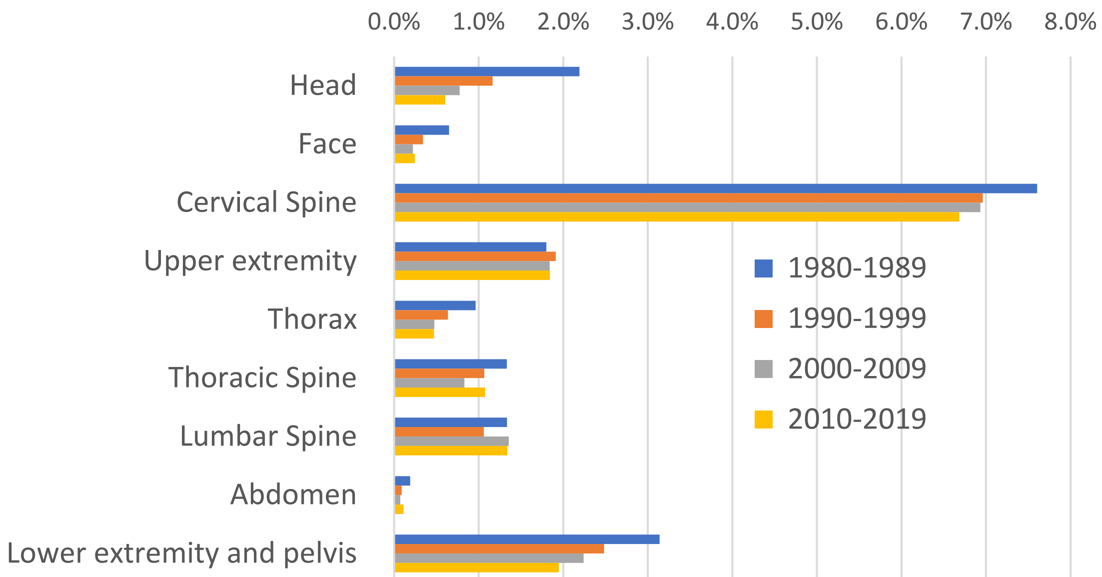

Fig. 5. Development of risk for PMI to different body regions for females for cars launched for the 10-year periods 1980–89 to 2010–19.

When studying the development in risk of PMI>1% for two age groups, 0–50 years and above 50 years, some differences can be seen (Figs 6 and 7 and Appendix). A larger reduction in risk for injuries leading to PMI to the head, face, upper extremities and abdomen was found for occupants above 50 years compared to those below 50 years. The risk for injuries to the cervical spine leading to PMI increased by approximately 14% for occupants younger than 50 years for the intervals in car introduction years studied, while the risk among those above 50 years decreased by 15%. However, an increased risk of PMI to the lumbar spine of more than 70% was found for older occupants.

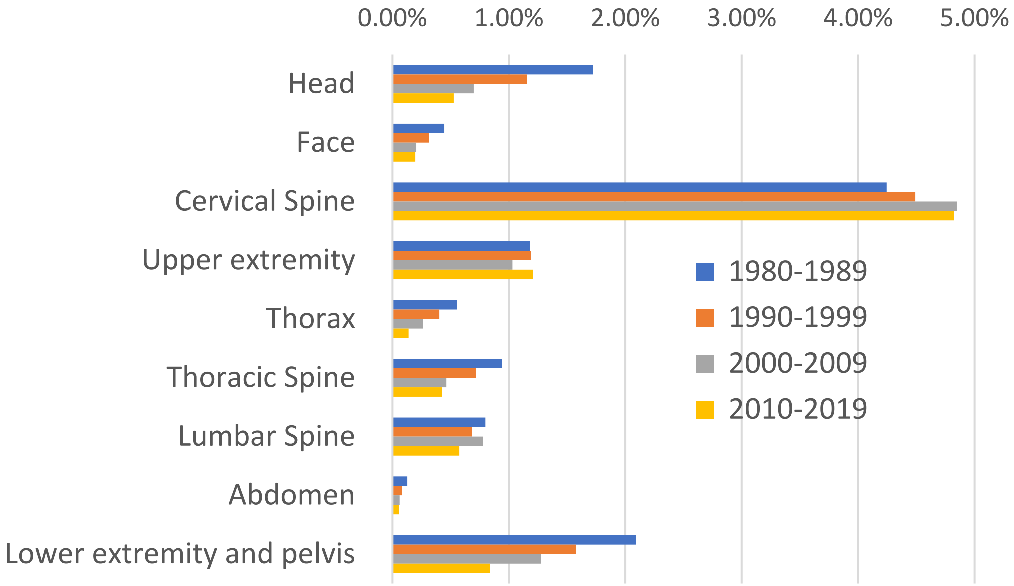

Fig. 6. Development of risk for PMI to different body regions for the age group 0–50 years age for cars launched for the 10-year periods 1980–89 to 2010–19.

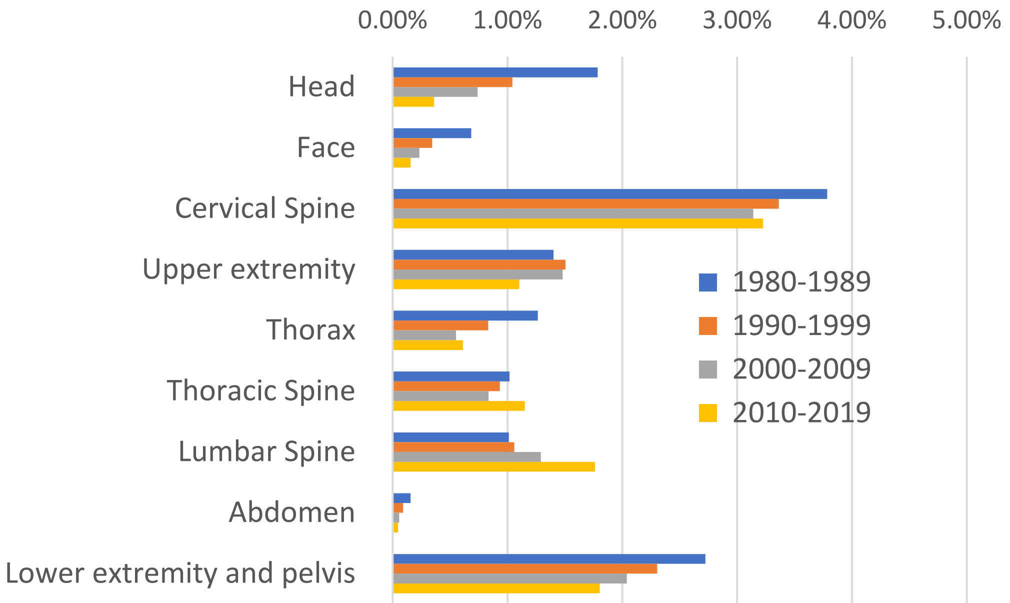

Fig. 7. Development of risk for PMI to different body regions for the age group above 50 years for cars launched for the 10-year periods 1980–89 to 2010–19.

IV. DISCUSSION

The results in this study clearly show that vehicle crashworthiness has improved since the 1980s. Such improvements have also been found in other studies [1,3,4,18]. The results also show that the improvements are larger for more severe injuries. The largest improvement was found for fatal injuries, but large improvements were also found for injuries leading to PMI. In Sweden, which has developed and adopted the Vision Zero approach, this is very positive, because the strategy includes reduction targets for both fatal and serious injuries, and in Sweden a serious injury is defined as an injury leading to any degree of PMI (PMI>1%).

Although large improvements in crash safety could be seen, both the risk levels and the reduction in risk over the years of introduction were not found to be equal for males and females and for different age groups. Females were found to have higher risk for all types of injury severity studied, except for fatal injury. However, in general the improvements in crashworthiness were larger for females. But the reduction in risk of injuries leading to PMI were the same for males and females, although the risk levels were higher for females. Looking at variation in risk for age groups, a higher risk for older occupants was found for all types of injury severity studied, except for minor injuries.

Several studies have shown that, compared to non-senior occupants, senior occupants have a higher risk of sustaining serious and fatal injuries [19-21] and therefore it has been argued that the risk reduction of modern occupant protection is lower for senior occupants compared to non-seniors [21]. Furthermore, senior occupants are also more likely to die from a less serious injury than a non-senior occupant due to increased vulnerability [22]. In the present study an increased risk was seen for occupants 50 years of age or older. The higher risk for older occupants was found for all types of injury severity studied, except for minor injuries. For fatal injuries the risk was two to three times higher for car models launched between 1980 and 1999. And for car models launched 2000 and later the difference in risk seems to increase. Future work in passenger protection should therefore take these differences into account. Equally improved passenger protection for all road users including the most vulnerable passengers is desirable, especially if the focus is shifted from fatal and serious injuries to injuries leading to PMI. Given the aging population, there will be a higher number of older drivers in the coming years and therefore a higher number of casualties. Improved protection for older car occupants is therefore important to consider.

The results presented here only show developments in vehicle crashworthiness. During the latest 10 years cars have been equipped with many systems shown to be effective in preventing or mitigating crashes [23-26]. Solutions like Automated Emergence Braking (AEB), designed to avoid crashes or to mitigate the crash severity, will have a substantial impact and will address all car occupants, regardless of age or gender. Some of the differences in vehicle crashworthiness observed in this study for males and females, as well as for occupants in different age groups, might change in the future. In most of the remaining crashes the crash severity will be lower and thereby survivable and hopefully most of the injuries can be avoided or prevented. Hence there is a need for improved occupant protection for all types of occupant within this severity range.

Large differences in development in injury risks were found for injuries to different body regions. The risk figures also differed when separated for gender and age. In general females had higher risk for injuries leading to PMI, and especially regarding injuries to the cervical spine, which is in line with another study [8]. Several studies have also shown a higher risk for females for AIS1 cervical spine injuries [27-31]. For injuries to most body regions the risk for PMI dropped when comparing car models launched 1980-1989 compared to 2010-2019, except for injuries to the spine. For males a small increase in risk was found for injuries to the cervical and lumbar spine, while for females a small decrease in risk could be seen for injuries to the cervical spine and no difference in risk regarding lumbar spine. Another interesting finding was that drivers below 50 years age had an increased risk of injuries to the cervical spine, while those above 50 had a decreased risk. For injuries to the lumbar spine it was the opposite, older drivers had an increased risk. Further research is needed to clarify the reason behind these differences.

Car occupants ≥46 years old have been shown to have a higher risk of AIS2+ spinal injuries [32]. As shown in the present study, these injuries have not decreased over the recent decades but rather have remained at a similar level [33] or even increased [34]. Only a few examples of car safety systems that target thoracic and lumbar spine injuries currently exist [36]. This warrants further studies on consequences of spinal injuries and how to effectively prevent them.

Limitations

A strength of this study is the large number of crashes, allowing for subgroup analyses. The data used is nationwide police and hospital data of high coverage and quality. However, when studying fatal crashes, very few occurred in cars launched during the last decade, resulting in wide CI.

It should be noted that the differences in development in risk among the groups studied reflects how the Swedish car fleet has improved over the years. It is important to keep in mind if generalizing the findings to other car fleets. For example, Sweden has a 25% market share of Volvo cars, which is much higher compared to other countries. The risk figures may be influenced by systematic differences in seatbelt use, age and gender in the car groups studied. Cars launched since 2010 that have seatbelt reminders might have a higher seatbelt use [36]. Those parameters were checked, the proportion of unbelted were higher in older cars and the proportion of older occupants were higher. Those reported to be unbelted were excluded from the analysis. However, differences in average age were not adjusted for. Another potential source of error could be that drivers of older cars have a different driver behavior than drivers in modern cars. This has not been checked or addressed. Another potential bias could be that some groups of cars with specific drivers more often are bullet cars than others. However, by using the pair comparison method both cars will experience the same crash severity, and such possible bias is to a large extent controlled for.

V. CONCLUSIONS

It was found that vehicle crashworthiness has improved steadily over the vehicle model years of introduction studied. The risk of all types of injury severity studied was found to be reduced, with the largest reductions for serious and fatal injuries, for fatal injuries and for injuries leading to PMI. Females were found to have higher injury risks for all types of injury severity studied (except for fatality risk). Furthermore, occupants older than 50 years were found to have significantly higher risk of fatal injuries compared to occupants younger than 50 years. When comparing car models introduced 2000–2009 with those introduced 2010–19, both the risk for serious and fatal injuries and fatal injuries alone was higher for occupants older than 50 years compared to those younger than 50 years. If all occupants should have the same level of protection, the higher fatality risk for older car occupants is important to address. When studying development in risk for PMI for injuries to different body regions, large variations were found between injured body regions, gender and age groups. For male occupants, as well as for occupants younger than 50 years, the risk for injury leading to PMI to the cervical spine was found to increase in modern cars. Occupants older than 50 years were also found to have an increased risk for injuries to the thoracic and lumbar spine. More research is needed on how to better protect injuries to the spine for occupants of different sex and age groups.

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VII. APPENDIX

TABLE A1

NUMBER OF CRASHES AND INJURIES DURING 10-YEAR PERIODS REGARDING VEHICLE YEAR OF LAUNCH FOR ANY INJURY, FATAL AND SERIOUS INJURY, FATAL INJURY, AND INJURIES LEADING TO PMI, DIVIDED FOR ALL OCCUPANTS, MALE AND FEMALE OCCUPANTS AND OCCUPANTS YOUNGER AND OLDER THAN 50 YEARS.

Injury severity	Year	n crashes, all oocupants	n PMI, all occupants	n crashes, males	n PMI, males	n crashes, females	n PMI, females	n crashes, occ. <50 years	n PMI, occ. <50 years	n crashes, occ. >50 years	n PMI, occ. >50 years
Any injury	1980-1989	41 669		25 429		15 894		28 695		12 645	
injury	1990-1999	56 670		34 031		22 085		37 975		18 121	
	2000-2009	28 990		17 159		11 492		18 662		9 973	
	2010-2019	5 287		3 128		2 105		3 318		1 909	
	Total	132 616		79 747		51 576		88 650		42 648	
Serious	1980-1989	39 254		23 905		15 036		26 841		12 117	
and fatal	1990-1999	56 189		33 650		21 722		37 371		17 959	
injury	2000-2009	38 604		22 767		15 133		25 337		12 521	
	2010-2019	9 438		5 527		3 753		6 191		3 076	
	Total	143 485		85 849		55 644		95 740		45 673	
Fatal	1980-1989	42 655		26 051		16 214		29 376		12 903	
injury	1990-1999	64 450		38 585		24 951		43 464		20 028	
	2000-2009	41 872		24 679		16 448		27 657		13 428	
	2010-2019	9 459		5 529		3 753		6 193		3 076	
	Total	158 436		94 844		61 366		106 690		49 435	
PMI	1980-1989	41 669	12 469	25 429	7 587	15 894	4 882	28 695	12 903	12 645	3 155
	1990-1999	56 670	47 830	34 031	26 526	22 085	21 304	37 975	20 028	18 121	13 698
	2000-2009	28 990	35 604	17 159	19 425	11 492	16 179	18 662	13 428	9 973	12 255
	2010-2019	5 287	6 376	3 128	3 170	2 105	3 206	3 318	3 076	1 909	2 512
	Total	132 616	102 279	79 747	56 708	51 576	45 571	88 650	49 435	42 648	31 620

TABLE A2

RELATIVE RISK DURING 10-YEAR PERIODS REGARDING VEHICLE YEAR OF LAUNCH FOR ANY INJURY, FATAL AND SERIOUS INJURY, FATAL INJURY, AND INJURY LEADING TO PMI, DIVIDED FOR ALL OCCUPANTS, MALE AND FEMALE OCCUPANTS AND OCCUPANTS YOUNGER AND OLDER THAN 50 YEARS.

Injury severity	**Year**	**Risk-all**	**95% CI**	**Risk -male**	**95% CI**	**Risk-female**	**95% CI**	**Risk < 50 years**	**95% CI**	**Risk > 50 years**	**95% CI**
Any injury	1980-1989	1,00	0,006	1,00	0,009	1,59	0,007	1,00	0,007	1,00	0,010
injury	1990-1999	0,91	0,006	0,93	0,008	1,41	0,009	0,94	0,007	0,88	0,010
	2000-2009	0,83	0,008	0,84	0,013	1,26	0,014	0,86	0,010	0,78	0,015
	2010-2019	0,78	0,021	0,79	0,030	1,19	0,037	0,80	0,026	0,75	0,034
	Reduction 1980-2019	22% +/-2%		21% +/-3%		25% +/-2%		20% +/-3%		25% +/-3%	
Serious	1980-1989	1,00	0,014	1,00	0,021	1,44	0,018	1,00	0,019	1,24	0,021
and fatal	1990-1999	0,82	0,015	0,83	0,022	1,14	0,023	0,83	0,020	0,97	0,024
injury	2000-2009	0,67	0,024	0,67	0,034	0,93	0,040	0,71	0,032	0,74	0,041
	2010-2019	0,67	0,055	0,71	0,076	0,86	0,093	0,56	0,075	1,01	0,080
	Reduction 1980-2019	33% +/-5%		29% +/-8%		40% +/-6%		44% +/-8%		18% +/-6%	
Fatal	1980-1989	1,00	0,032	1,00	0,042	1,57	0,124	1,00	0,070	2,92	0,189
injury	1990-1999	0,66	0,044	0,76	0,053	0,73	0,088	0,69	0,107	1,66	0,122
	2000-2009	0,36	0,082	0,39	0,105	0,46	0,155	0,29	0,169	1,08	0,173
	2010-2019	0,34	0,178	0,50	0,220	0,20	0,322	0,16	0,346	1,68	0,502
	Reduction 1980-2019	66% +/-17%		50% +/- 22%		87% +/-21%		84% +/-35%		43% +/-17%	
PMI	1980-1989	1,00	0,024	1,00	0,029	1,44	0,057	1,00	0,026	1,22	0,045
	1990-1999	0,72	0,011	0,74	0,015	1,01	0,024	0,73	0,013	0,85	0,020
	2000-2009	0,57	0,012	0,57	0,016	0,81	0,025	0,57	0,015	0,67	0,019
	2010-2019	0,50	0,026	0,50	0,036	0,73	0,053	0,50	0,033	0,59	0,040
	Reduction 1980-2019	50% +/-3%		50% +/- 4%		50% +/- 4%		50% +/-3%		52% +/-3%	

TABLE A3

NUMBER OF INJURIES FOR OCCUPANTS IN CRASHES WITH VEHICLES IN 10-YEAR PERIODS REGARDING VEHICLE YEAR OF LAUNCH FOR INJURIES LEADING TO PMI FOR VARIOUS BODY REGIONS DIVIDED FOR MALE AND FEMALE OCCUPANTS AND OCCUPANTS YOUNGER AND OLDER THAN 50 YEARS.

	Year of launch	Head	Face	Cervical Spine	Upper extremity	Thorax	Thoracic Spine	Lumbar Spine	Abdomen	Lower extremity and pelvis	(Skin) and Thermal Injuries	Total
males	1980-1989	525	289	1 599	394	1 207	247	241	218	453	4 002	9 175
	1990-1999	1 567	755	6 013	1 378	3 263	707	905	535	1 225	12 735	29 083
	2000-2009	991	425	4 998	1 019	1 787	419	776	312	827	8 835	20 389
	2010-2019	146	66	925	173	355	67	173	38	115	1 445	3 503
	Total	3 229	1 535	13 535	2 964	6 612	1 440	2 095	1 103	2 620	27 017	62 150
females	1980-1989	247	119	1 299	198	654	135	141	109	215	2 185	5 302
	1990-1999	963	343	5 959	1 065	2 117	519	661	272	820	9 465	22 184
	2000-2009	660	227	5 111	842	1 369	292	587	183	638	6 969	16 878
	2010-2019	149	55	1 085	179	304	58	132	64	127	1 398	3 551
	Total	2 019	744	13 454	2 284	4 444	1 004	1 521	628	1 800	20 017	47 915
occ. < 50 y	1980-1989	593	285	2 362	440	1 126	303	289	236	466	4 763	10 863
	1990-1999	1 873	776	9 478	1 655	2 843	871	1 117	529	1 299	16 397	36 838
	2000-2009	1 115	406	7 684	1 066	1 309	397	843	308	788	10 459	24 375
	2010-2019	199	75	1 450	213	181	38	149	63	101	1 729	4 198
	Total	3 780	1 542	20 974	3 374	5 459	1 609	2 398	1 136	2 654	33 348	76 274
occ. > 50y	1980-1989	179	123	536	152	735	79	93	91	202	1 424	3 614
	1990-1999	657	322	2 494	788	2 537	355	449	278	746	5 803	14 429
	2000-2009	536	246	2 425	795	1 847	314	520	187	677	5 345	12 892
	2010-2019	96	46	560	139	478	87	156	39	141	1 114	2 856
	Total	1 468	737	6 015	1 874	5 597	835	1 218	595	1 766	13 686	33 791

TABLE A4

RELATIVE RISK AND REDUCTION FOR OCCUPANTS IN CRASHES WITH VEHICLES IN 10-YEAR PERIODS REGARDING VEHICLE YEAR OF LAUNCH FOR INJURIES LEADING TO PMI FOR VARIOUS BODY REGIONS DIVIDED FOR MALE AND FEMALE OCCUPANTS AND OCCUPANTS YOUNGER AND OLDER THAN 50 YEARS.

Risk for PMI for body regions (per cent)

	Year of launch	Head	Face	Cervical Spine	Upper extremity	Thorax	Thoracic Spine	Lumbar Spine	Abdomen	Lower extremity and pelvis	(Skin) and Thermal Injuries	Total
males	1980-1989	1,9%	0,6%	3,7%	1,3%	0,8%	1,0%	0,9%	0,1%	2,4%	1,4%	14,2%
	1990-1999	1,4%	0,4%	3,9%	1,3%	0,6%	0,9%	0,9%	0,1%	1,9%	1,0%	12,4%
	2000-2009	0,9%	0,3%	4,0%	1,2%	0,4%	0,7%	1,0%	0,1%	1,6%	0,7%	10,9%
	2010-2019	0,5%	0,2%	4,0%	1,1%	0,4%	0,8%	1,3%	0,0%	1,2%	0,6%	10,2%
	1980-89 - 2010-19	72,7%	63,9%	-6,9%	11,6%	53,3%	24,6%	-51,5%	77,7%	48,5%	55,6%	12,4%
females	1980-1989	2,2%	0,6%	7,6%	1,8%	1,0%	1,3%	1,3%	0,2%	3,1%	2,1%	21,3%
	1990-1999	1,2%	0,3%	7,0%	1,9%	0,6%	1,1%	1,1%	0,1%	2,5%	1,4%	17,1%
	2000-2009	0,8%	0,2%	6,9%	1,8%	0,5%	0,8%	1,4%	0,1%	2,2%	1,0%	15,8%
	2010-2019	0,6%	0,2%	6,7%	1,8%	0,5%	1,1%	1,3%	0,1%	1,9%	0,8%	15,2%
	1980-89 - 2010-19	72,5%	62,2%	12,1%	-2,3%	51,1%	19,4%	-0,3%	42,1%	38,0%	60,0%	17,8%
occupant < 50 y	1980-1989	1,7%	0,4%	4,2%	1,2%	0,6%	0,9%	0,8%	0,1%	2,1%	1,4%	13,5%
	1990-1999	1,2%	0,3%	4,5%	1,2%	0,4%	0,7%	0,7%	0,1%	1,6%	1,0%	11,6%
	2000-2009	0,7%	0,2%	4,8%	1,0%	0,3%	0,5%	0,8%	0,1%	1,3%	0,7%	10,4%
	2010-2019	0,5%	0,2%	4,8%	1,2%	0,1%	0,4%	0,6%	0,1%	0,8%	0,6%	9,4%
	1980-89 - 2010-19	69,4%	55,8%	-13,7%	-2,3%	74,9%	54,6%	28,0%	56,8%	59,9%	57,0%	12,4%
occupants > 50y	1980-1989	1,8%	0,7%	3,8%	1,4%	1,3%	1,0%	1,0%	0,2%	2,7%	1,3%	15,1%
	1990-1999	1,0%	0,3%	3,4%	1,5%	0,8%	0,9%	1,1%	0,1%	2,3%	0,9%	12,4%
	2000-2009	0,7%	0,2%	3,1%	1,5%	0,6%	0,8%	1,3%	0,1%	2,0%	0,7%	11,0%
	2010-2019	0,4%	0,2%	3,2%	1,1%	0,6%	1,2%	1,8%	0,0%	1,8%	0,6%	10,8%
	Difference 1980-89 -	79,8%	77,3%	14,7%	21,3%	51,7%	-13,2%	-74,2%	69,9%	33,8%	58,0%	12,6%