Compact accident research No. 120

Occupant injury severity and gender: Evidence for a gender gap?

Unfallforschung
der Versicherer

GDV

Imprint

MIX
Aus verantwortungs-
vollen Quellen
FSC® C126256
FSC
www.fsc.org

Contents

Abstract

For some time, society has increasingly been using the term "gender gap" to discuss whether women are under-represented compared to men as beneficiaries of research and development and whether insufficient consideration is paid to their gender-related specificities. In this context, it has been objected that dummies based on the anatomical and biomechanical data for normal adult males are almost exclusively used during crash tests. A number of studies, mostly based on US NASS-CDS data have calculated odds ratios considerably above 1.0 of female car occupants sustaining MAIS2+ and MAIS3+ injuries compared to men. These studies differ considerably in terms of their boundary conditions, such as the considered seat positions and the directions of impact at the vehicle.

The aim of the present study was to determine the influence of gender on the risk of serious injury to car occupants on the basis of German accident data. To this end, on the one hand, data for female and male drivers and occupants taken from the national accidents statistics were compared and, on the other, logistical regressions were run on 1.713 car occupants represented in the case material of the insurers' accident database (UDB), with gender, seat position and age, as well as curb weight and year of initial registration of the car and impact orientation as variables.

If no distinction is made based on impact type, females have an odds ratio of 1.021 compared to males of sustaining an MAIS2+ versus an MAIS0-1 injury (uninjured or slightly injured). If the analysis is restricted to front impacts then the odds ratio for females is 1.125 compared to males. The regression models therefore indicate that females are exposed to a tendentially higher risk, although at a non-significant odds ratio which is considerably lower than in American studies. Considerably greater and significant effects are observed for the front passenger seat position compared to the driver's seat position, the age of the occupants and the vehicle's curb weight. In the case of rear-impact collisions, the model only explains a small amount of the variance and indicates almost no significant effects for the considered variables. The only exception is gender, with an odds ratio of 3.345 of females being injured (MAIS1+) versus remaining uninjured (MAIS0) when compared to males.

Introduction

Within the context of a general social debate about diversity and participation, criticism has been expressed at the failure to take adequate account of the gender-specific characteristics of human beings – which can also include anatomical or physiological specificities – in the fields of science, development and standardization and this shortfall has been described in terms of a "gender gap". In this context, passive vehicle safety and the methods used to evaluate it have also been called into question [1], [2]. Particular attention has been focused on the still widespread Hybrid III generation of anthropomorphic test devices that are used in standard front crash tests, the 50th percentile male version of which is intended to represent a male of above-average height and weight. Even though other dummies, including the 5th percentile female dummy, are increasingly being used for vehicle development and consumer tests in order to represent a wider spectrum of adult body sizes, there has nevertheless been considerable criticism that insufficient attention is paid to female occupants during the development of passenger vehicle safety systems [1], [2].

Studies concentrating on male and female injury probabilities independently of the gender-specific risk of being involved in an accident as a vehicle user come primarily from the USA, where the collected data provides considerably higher numbers of cases of casualties of car occupants than in Europe or Germany.

Evans analysed data taken from FARS (Fatality Analysis Reporting System) relating to road traffic accidents resulting in fatalities in the USA for the years 1975 to 1998 [3]. "Double pair comparisons" were performed to examine accidents with two front vehicle occupants of whom one was fatally injured. For belt-restrained drivers, Evans identified that the risk of females aged approximately 20 years being fatally injured was 1.15 times that of males of the same age. In the case of unbelted females sitting in the driver's seat, the risk was 1.36-fold. As of approximately 50 years, the risk was equally high for both genders and, among elderly drivers, there were indications that the risk for females was slightly lower. With regard to vehicle occupants in the passenger seat, the results were somewhat less clear-cut but still indicated a tendentially higher risk of a fatal outcome for females. Bose et al. analysed data from the US NASS-CDS (National Automotive Sampling System) for the years 1998 to 2008 for belt-restrained, injured drivers as of the age of 16 years in passenger cars, "vans" and "light trucks" [4]. Female drivers had an average age of 36.7 years and were therefore marginally older than their male equivalents (36.4 years) but were considerably shorter and lighter (164.2 cm versus 177.8 cm and 68.0 kg versus 83.9 kg). Females were significantly more often the victims of accidents in conventional cars (74% versus 61%) and less often in light trucks (3% versus 18%) than males. A multivariate logistical regression revealed an odds ratio of 1.71 for MAIS2+ and 1.47 for MAIS3+ injuries for female compared to male drivers. However, the distribution of the crash types in the data material appears unusual, with barely 3 percent frontal crashes, but approximately 43 percent side crashes and 23 percent rear crashes.

In their 2019 study, Forman et al. again drew on the NASS-CDS, in this case using data for the years 1998 to 2015 [5]. They considered belt-restrained drivers, passengers and occupants in the second row of seats in cars involved in frontal collisions. The analysis focused on AIS2+ injuries in different regions of the body in more recent (model years as of 2009) and older vehicles (model years up to 2008) as well as the risks of MAIS2+ and MAIS3+ injuries for female and male occupants. A multivariate logistical regression revealed an odds ratio of 2.42 for MAIS2+ and 1.73 for MAIS3+ injuries for female compared to male occupants. The odds ratio of 3.05 for injuries of the lower extremities was striking. In addition, compared to men, females had odds ratios of about 2.0 for AIS2+ injuries of the cervical spine and abdomen and AIS3+ rib fractures.

Again making use of NASS-CDS data for the years 1998 to 2015, Brumbelow et. al. [6] used logistical regressions to analyse the injury frequency and severity of belt-restrained drivers in the case of front crashes as well as of struck-side occupants in the front row of seats in side crashes, while taking account of a number of accident and vehicle-related variables such as vehicle category and "compatible" vehicle-to-vehicle crash configurations. While the analysis of all front crashes revealed odds ratios of 3.11 for MAIS2+ and 1.92 for MAIS3+ injuries for female compared to male drivers, this value was reduced when only "compatible" crashes in which airbags were triggered were considered. These included single-vehicle crashes involving no other party, front-to-rear collisions and front-to-front collisions between cars with weight differences of less than 454 kg. In such cases, the odds ratios for female drivers were nevertheless still 2.23 for MAIS2+ injuries and 1.95 for AIS2+ injuries to the upper extremities and 2.72 for AIS2+ injuries to the lower extremities. By contrast, there was no longer any significant difference between female and male drivers regarding injuries to other body regions and MAIS3+ injuries. With regard to side impacts, the results were unclear and not significant, with odds ratios of 0.92 for MAIS2+ and 1.55 for MAIS3+ for female compared to male occupants. In the "car" and "pick-up" vehicle categories, the median weight of vehicles driven by males was approximately 40 kg greater than those driven by females.

Seen in this context, the work of Linder et al. starts by providing an overview of the use of various anthropomorphic test dummies in EU legislation and consumer crash tests [2]. They show that dummies representing an average-sized male are the most frequently used in commonly practised crash tests and that the ECE regulations provide for the 5th percentile female dummy as a representative of a small female adult occupant only for front crashes as specified in ECE-R137 and only on the passenger seat. The authors demand the development of a dummy representing an average-sized female and point to approaches to developing a 50th percentile female BioRID (Biofidelic Rear Impact Dummy) for testing seats with regard to protection against distortion of the cervical spine in the event of rear impacts.

Studies conducted in Germany have either primarily been concerned with the relationships between gender-related driving behaviour and the risk of causing or being involved in an accident as driver or passenger [7], [8], or are, as in the case of the special analyses conducted by the German Federal Statistical Office [9], purely descriptive in nature. By contrast, it appears that no more recent research work has been conducted in the German-speaking world to investigate the gender-specific injury risk independently of the accident risk. It is not immediately possible to assume that knowledge gained from US studies can be transferred to the European context because of potential differences not only in the vehicle fleets and accident occurrence but also, in part, the anthropometric characteristics of the vehicle occupants, for example in terms of the proportion of obese occupants [10]. The aim of the current work was therefore to analyse German accident and injury data to determine the extent to which the probabilities of injury differ for female and male car occupants and provide indications regarding a gender gap in the national vehicle fleet.

Method

Two different methods were used to address the task described above. On the one hand, the data freely available from the German Federal Statistical Office on the number of car occupants involved in accidents, subdivided by gender, was processed and also provided a longer-term view of injury trends. On the other, data from the insurers' accident database (UDB) was analysed. This data includes not only the gender of the occupants and their injuries but also, for example, information on the type of collision and the vehicle characteristics.

The national statistics provide a good overview of the severity of injuries suffered by car occupants and their development over time. Table UJ 10 of the Federal Statistical Office's annually published record of "Traffic accidents" [11] includes all the car occupants injured in accidents, subdivided in accordance with the official definitions of injury severity into "Fatality" (death within 30 days following the accident), "Seriously injured" (casualty admitted as an inpatient immediately after the accident and remaining hospitalised for a minimum of 24 hours) and "Slightly injured" (all other casualties). This data is further subdivided into tranches of age of five years each and these are in turn further subdivided in the case of young people and adolescents. Casualties aged 75 years or more are combined into a single group. Table UJ 37 also distinguishes between drivers and passengers. This latter group comprises not only vehicle occupants on the front passenger seat but also persons in the rear of the vehicle. The statistical data recorded for the years 1999 and 2019 was compared.

The insurers' accident database (UDB) provides more detailed information about accidents, the vehicles involved and the injuries to occupants. It contains information taken from randomly selected claim files of German motor vehicle liability insurers relating to accidents involving personal injury with estimated damage costs of at least 15,000 euros. This amount includes values

for both personal injury and damage to property. For the purposes of the present study, the selection of cases was restricted to the occupants of cars which had collided with other cars or light goods vehicles, like delivery vans, in order to ensure a priori a certain level of compatibility between the parties involved in the collision.

The selected characteristics were examined for possible gender-dependence. In addition, logistical regressions were run on a subset of the statistical evaluations of the different impact types using the SPSS® [12] program in order to examine the influence of variables other than gender on injury severity.

Vehicles with an initial year of registration prior to 1991 or a curb weight of less than 700 kg were excluded from the analysis. In additional analyses, the main impact at the car – in the case of multiple collisions, the more severe of the impacts, which was therefore also presumably the cause of the injury – was categorized as a front, side or rear impact. Other impact types, for example against the roof or floor of the vehicle, were excluded. In addition, for some of the analyses, the degree of damage to the side of the vehicle at which the main impact occurred was also taken into account. The degree of damage (DoD) is rated on the basis of the deepest deformation and coded into categories from 1 (minor dents) to 5 (massively or completely deformed passenger compartment) and acts as a proxy variable reflecting the generated deformation energy and, consequently, the impact-induced change of speed. Two groups were formed for the analysis. Minor damage (DoD1 – DoD2) and severe damage (DoD3 – DoD5). In addition, the location of the accident – inside or outside (including motorways) of a built-up area – was taken into account in order to provide a general idea of the speeds involved.

With regard to the vehicle occupants, adults aged 18 years or more and of known gender and known seat position were included in the analysis: Drivers, front-seat passengers and occupants seated on the second row of seats. Injury severity was coded in accordance with AIS 2005, Update 2008 [13] and the Maximum AIS (MAIS) was used as an indicator of overall injury severity in the analysis. Occupants with unknown MAIS (MAIS9) were not considered in the analysis. In cases where the pattern of injury was not fully known due to isolated missing AIS specifications for certain body regions, the MAIS was conservatively coded on the basis of the documented injuries.

The occupants' body size and weight were not considered in the analysis due to the large number of missing values. Because, in some cases, there was no information whatsoever about belt use or, in particular in the case of more minor accidents, this information was based on statements made by the vehicle occupants themselves, this characteristic was also ignored. No assumptions regarding missing values, weightings or extrapolations were performed.

To test for the statistical significance of differences between the considered groups, t-tests were used for continuous variables and chi-square tests were used for dichotomous variables. The threshold for statistical significance was defined as $p = 0.05$; otherwise the difference was considered to be non-significant (n.s.).

Results

Analysis of the national accident statistics

Even though not surprising, there is nevertheless a striking fall in the absolute number of fatally and seriously injured car occupants between 1999 and 2019 which makes a great contribution to the reduction in the overall number of road traffic fatalities and serious injuries during this period. In total, the number of fatally injured male drivers fell by 68.6 percent to 812 and that of fatally injured female drivers by 65.2 percent to 252 (Fig. 1). The number of fatally injured male passengers during this period fell by a total of 79.6 percent to 141 and the corresponding number of female passengers fell by 75.3 percent to 158 (Fig. 1).

Relative change in number of fatally injured car occupants

Figure 1 · **Percentage change in the number of fatalities as male/female car driver (left) and male/female car passenger (right), subdivided by gender and age for the period 1999 to 2019**

■ *Females, killed* ■ *Males, killed*

Killed drivers, 2019 vs. 1999

**Killed passengers**, 2019 vs. 1999
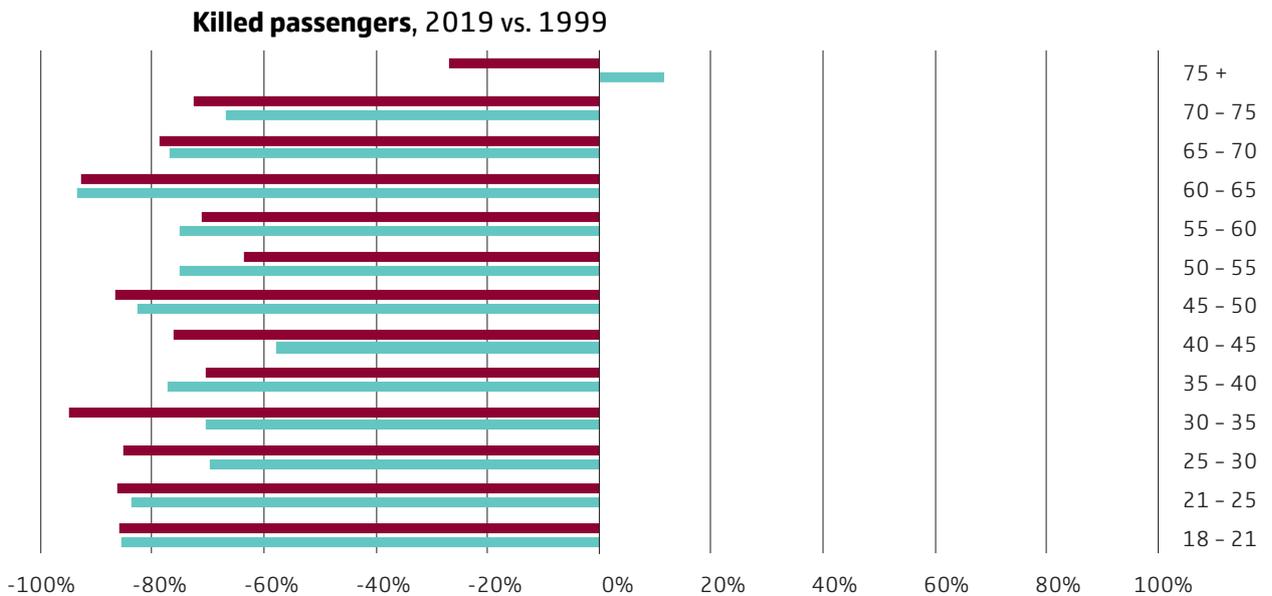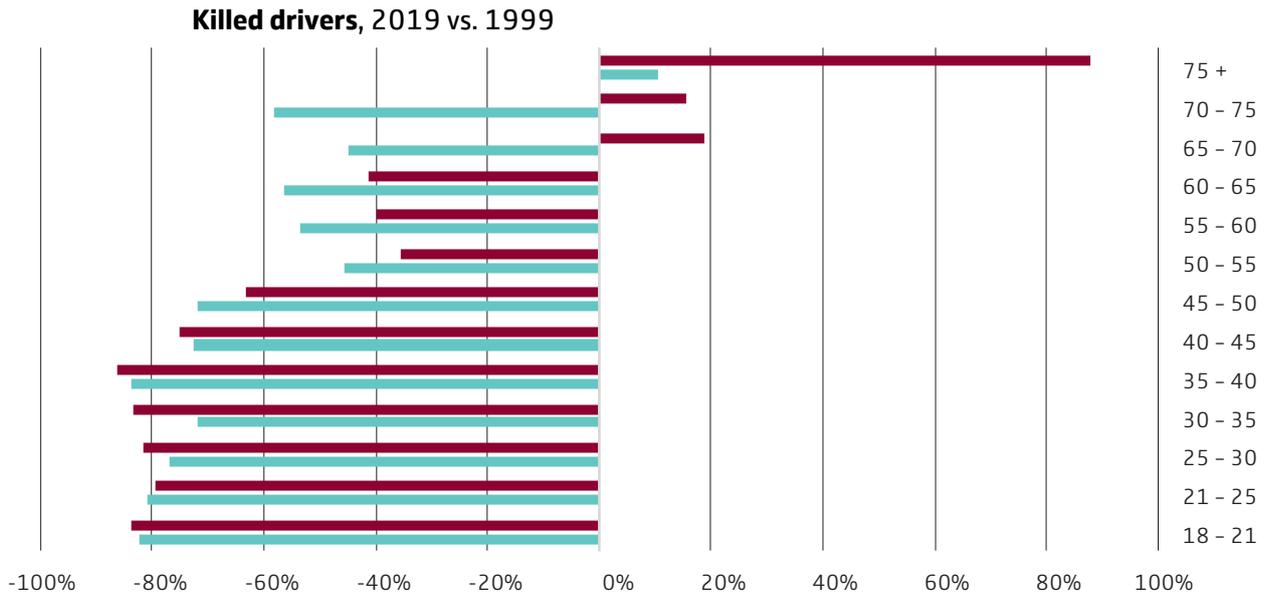
© UDV 2022

The charts represent the relative change in the number of fatalities between 1999 and 2019 for each age group. Although there is no indication of the absolute numbers of fatalities, these values nevertheless differ considerably between the individual age groups.

Given the aims of the present study, the change in the number of seriously injured car occupants between 1999 and 2019 is of even greater interest. Here again, considerable falls can be observed, even if not to the same extent as for the fatalities. The number of seriously injured male drivers fell by 49.2 percent and the number of seriously injured female drivers by 37.5 percent (Fig. 2). It is noteworthy here that the change in male drivers as of the age of approximately 50 years reaches a plateau, with the number of seriously injured drivers falling only minimally compared to 1999, before the corresponding number doubles compared to 1999 in the age group of 75-year-olds and over. In the case of seriously injured female drivers, the decreasing trend is reversed as of the age of approximately 50 years. In the age group as of 75 years, the value is almost three times as high as it was in 1999. The number of seriously injured male passengers fell by a total of 60.6 percent and the fall in the number of seriously injured female passengers was only slightly less at 58.7 percent. Over a wide age span, the number of seriously injured passengers of both genders fell by between 40 percent and 60 percent. It is only as of the age of 75 years that the number of seriously injured female passengers once again reaches the level of 1999, whereas that of male passengers increases to 1.6 times that of 1999 (Fig. 2).

Relative change in number of seriously injured car occupants

Figure 2 · **Percentage change in the number of seriously injured male/female car drivers (left) and male/female car passengers (right) subdivided by gender and age for the period 1999 to 2019**

■ *Females, seriously inj.* ■ *Males, seriously inj.*

Seriously injured drivers, 2019 vs. 1999


Seriously injured passengers, 2019 vs. 1999
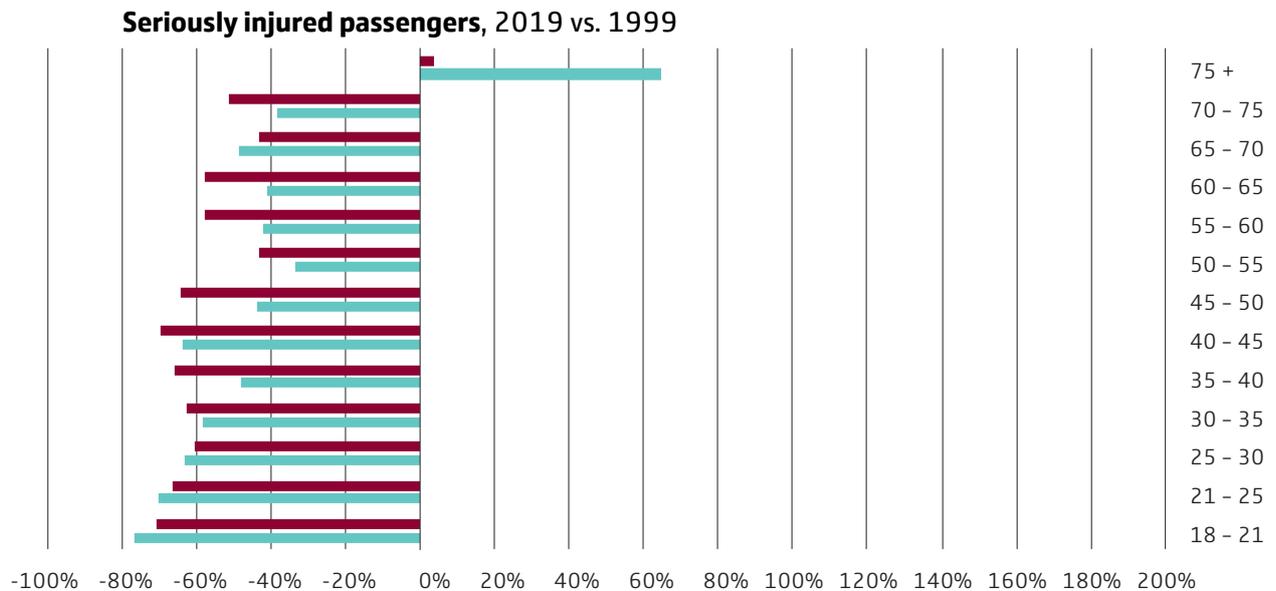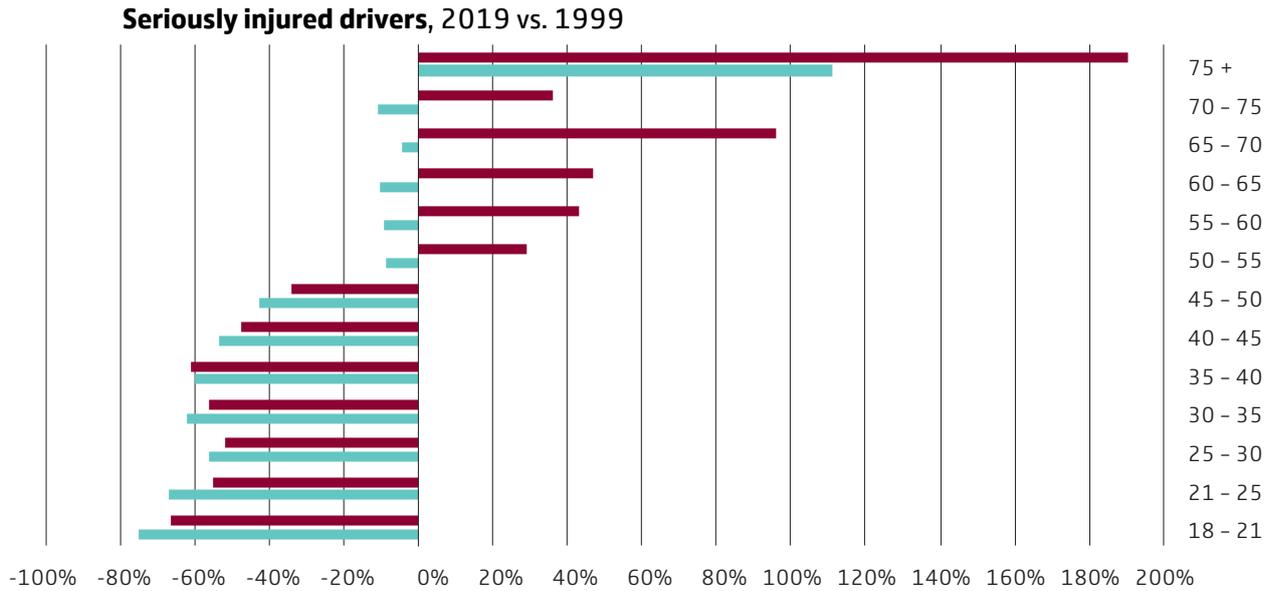
© UDV 2022

These observations do not make it possible to identify the effect of other influences that might lead to a decrease or increase in the number of casualties, for example an increase in the proportion of female drivers. The number of seriously injured occupants as a proportion of the total number of casualties, i.e. the total number of all injuries and fatalities, within a gender category provides a better indicator of whether female car occupants are exposed to a greater risk of serious injury than their male counterparts (Fig. 3). For female drivers in all age groups and for female passengers up to the age of approximately 55 years, the 2019 data clearly indicates a lower proportion of serious injuries than is observed in males. Above this age, the proportion of seriously injured female and male passengers follows an irregular pattern.

Relative share of seriously injured car occupants

Figure 3 · Percentage of seriously injured drivers/passengers as a proportion of all casualties among male/ female car drivers (left) and male/female car passengers (right) subdivided by gender and age in 2019

■ *Females, seriously inj.*   ■ *Males, seriously inj.*

Seriously injured drivers, 2019

Seriously injured passengers, 2019
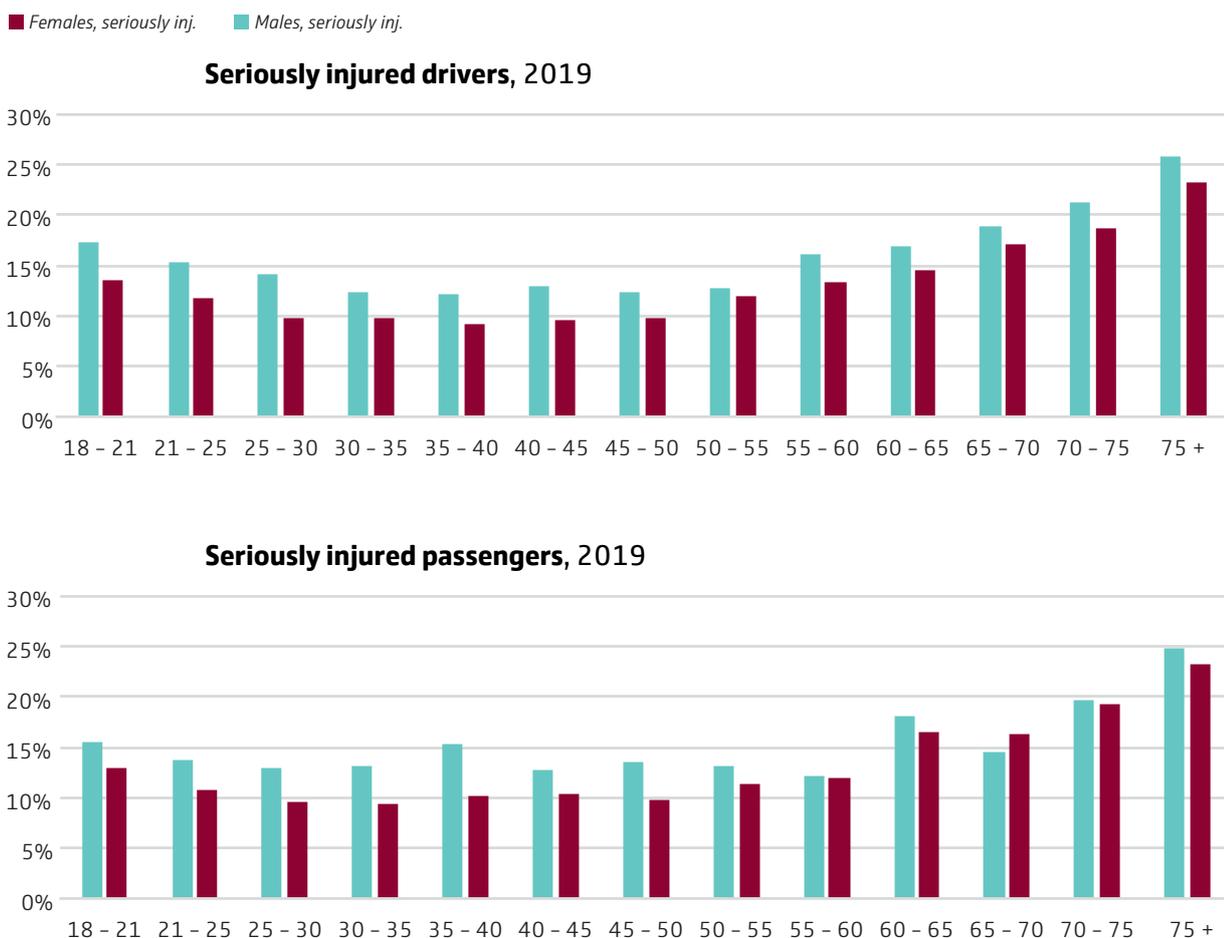
© UDV 2022

Analysis of the insurers' accident database (UDB)

After records for which there were no values for the gender, age or injury severity of the occupants had been excluded, the remaining sample comprised 1,713 individual data records for persons seated in the first and second row of seats in cars that had collided with other cars or light goods vehicles during the years 2009 to 2018. 759 of these were female and 954 male. The proportion of occupants seated on the driver's seat was 77.5 percent (n = 1,328), on the front passenger seat 18.3 percent (n = 313) and that of occupants on the second row of seats only 4.2 percent (n = 72). Front crashes as the main impact for the car and its occupants accounted for half of the cases and side and rear crashes for approximately a quarter each, for 2.5 percent

(n = 42) the impact direction could not be determined (Table 1). The proportions of female occupants differed only slightly for the different impact types. With regard to seating position, however, females were less frequently seated in the driver's seat (37.7 %, n = 500), but accounted for the majority of the occupants on the seats in the second row (54.2 %, n = 39) and, more particularly, the front passenger seat (70.3 %, n = 220). The average ages of the female and male occupants for the different impact types did not differ significantly. It was noteworthy however that, even though female and male drivers were similar in terms of their average age (for front impacts: 42.3 years versus 44.9 years; n.s.), female occupants on the passenger seat were considerably older than the corresponding male occupants (for front impacts: 51.3 years versus 38.7 years; p < 0.01).

Descriptive statistics

Table 1 · Relative frequency of MAIS0 (uninjured), MAIS1, MAIS2+ and MAIS3+ among car occupants by impact type and gender

Direction of impact	Proportion	Gender	N	Proportion	Ø Age [years]	MAIS0	MAIS1	MAIS2+	MAIS3+
All impact types	100%	female	759	44.3%	44.2	20.6%**	65.3%**	14.1%	4.6%
		male	954	55.7%	43.1	32.7%	56.3%	11.0%	4.2%
Front impact	50.8%	female	382	43.9%	45.3	28.3%*	52.6%	19.1%	6.3%
		male	489	56.1%	43.9	38.7%	46.8%	14.5%	5.1%
Side impact	22.7%	female	168	43.2%	44.4	16.1%**	70.2%*	13.7%	3.0%
		male	221	56.8%	42.2	30.3%	59.7%	10.0%	4.5%
Rear impact	24.0%	female	193	47.0%	42.3	5.7%**	90.2%**	4.1%	2.1%
		male	218	53.0%	42.5	17.0%	78.0%	5.0%	1.8%

Significant differences (female versus male): * = p < 0.05   ** = p < 0.01

Direct comparison of the proportional values of injury severity as a function of gender shows that females in all crashes with no distinction being made between impact type were, at 20.6 percent, significantly less frequently uninjured (MAIS0) than males at 32.7 percent (p < 0.01). By contrast, at 65.3 percent, they significantly more frequently sustained MAIS1 injuries (p < 0.01). This tendency was also confirmed when a distinction was made between impact types. MAIS2+ injuries following front and side impacts and MAIS3+ following front impacts were slightly more frequent among females. By contrast, males more frequently sustained MAIS3+ injuries following side impacts and slightly more MAIS2+ injuries following rear impacts. However, given the small overall number of cases for MAIS2+ and MAIS3+ injuries, these differences were not significant. There was no signifi-

cant difference between the number of belt-restrained females and males, determined on the basis of cases in which belts were demonstrably worn or not (95.2 % versus 91.7 %; n.s.). However, at 60.0 percent, females had significantly more accidents in built-up areas than males at 51.9 percent (p < 0.01).

The cars with female occupants were, on average, slightly newer than those with male occupants (initial registration 2005.8 versus 2005.0; p < 0.01), but had an average curb weight that was 100 kg lighter (1299.4 kg versus 1399.8 kg; p < 0.01).

The results of the logistical regression analysis for all impact types taken together and for front and rear impacts separately are shown in Tables 2, 3 and 4. The odds ratios of sustaining an MAIS2+ injury relative to the probability of an MAIS0-1 outcome (uninjured or

Regression analysis

Table 2 · **Results of the logistical regression analysis for car occupants and all impact types; odds ratios for MAIS2+ relative to MAIS0-1 used as a reference value.**

		Regression coefficient B	Standard error	Significance	Exp (B) (Odds Ratio)	95% confidence interval	
						Lower bound	Upper bound
MAIS2+	Age of occupant [years]	0.030	0.005	0.000	1.030	1.021	1.039
	Curb weight of vehicle [kg]	-0.001	0.000	0.000	0.999	0.998	0.999
	Initial registration year of vehicle	-0.054	0.016	0.001	0.947	0.917	0.978
	Gender: female	0.020	0.188	0.914	1.021	0.706	1.475
	Gender: male (reference)	0					
	Seat position: front passenger	0.736	0.210	0.000	2.088	1.383	3.152
	Seat position: rear passenger	0.581	0.358	0.105	1.788	0.886	3.610
	Seat position: driver (reference)	0					
	Degree of Damage DoD3-5	1.950	0.184	0.000	7.031	4.906	10.074
	Degree of Damage DoD1-2 (ref.)	0					
	Location: non-built-up area	0.419	0.181	0.021	1.520	1.066	2.169
	Location: built-up area (ref.)	0					

minor injury) were calculated for "all impact types" and for front impacts. By contrast, in the case of rear impacts, the odds ratio for the occurrence of an injury independently of severity (MAIS1+) was calculated relative to the absence of any injury because this impact type is dominated by MAIS1 injuries. It was not possible to calculate the MAIS3+ odds ratios for any of the impact types considered here due to insufficient case numbers.

The number of cases of side impacts was too small for this type of regression analysis.

A regression analysis performed on 1,489 valid records for "all impact types" (Table 2) yields a significant model (p < 0.01) which explains between 16 and 29 percent of variance (pseudo R^2). The odds ratio of female

occupants sustaining an MAIS2+ versus an MAIS0-1 injury compared to men is 1.021. However, this effect is not significant. With regard to the seat position, by contrast, the odds ratio of sustaining an MAIS2+ versus an MAIS0-1 injury is 2.088 for the passenger seat compared with the driver's seat (p < 0.01) and a seat position in the second row also has an odds ratio of 1.788 (n.s.). Significant effects were also observed for age of occupant, curb weight and year of initial registration of vehicle (p < 0.01). The table indicates the odds ratios if the values for these metric variables are increased by one unit, i.e. if the curb weight is increased by one kilogram and the occupant's age and year of initial registration of the vehicle are increased by one year.

Regression analysis

Table 3 · **Results of the logistical regression analysis for car occupants and front impact; odds ratios for MAIS2+ relative to MAIS0-1 used as a reference value**

		Regression coefficient B	Standard error	Significance	Exp (B) (Odds Ratio)	95% confidence interval	
						Lower bound	Upper bound
	Age of occupant [years]	0.035	0.006	0.000	1.035	1.024	1.047
	Curb weight of vehicle [kg]	-0.002	0.000	0.001	0.998	0.998	0.999
	Initial registration year of vehicle	-0.045	0.022	0.042	0.956	0.916	0.998
	Gender: female	0.117	0.244	0.630	1.125	0.698	1.813
	Gender: male (reference)	0					
MAIS2+	Seat position: front passenger	0.893	0.269	0.001	2.443	1.442	4.140
	Seat position: rear passenger	-0.218	0.515	0.673	0.804	0.293	2.208
	Seat position: driver (reference)	0					
	Degree of Damage DoD3-5	2.013	0.241	0.000	7.483	4.663	12.010
	Degree of Damage DoD1-2 (ref.)	0					
	Location: non-built-up area	0.615	0.232	0.008	1.849	1.173	2.915
	Location: built-up area (ref.)	0					

The model for front impacts based on 747 valid records (Table 3) is also significant (p < 0.01) and explains between 21 and 35 percent of the variance (pseudo R^2). However, the odds ratio of 1.125 of female occupants sustaining an MAIS2+ versus an MAIS0-1 injury when compared to men is again non-significant. The passenger seat has an odds ratio of 2.443 (p < 0.01) compared to the driver's seat; the odds ratio of 0.804 for rear seat passengers is not significant. Significant effects are again observed for occupant age and vehicle curb weight (p < 0.01) as well as year of initial registration (p < 0.05).

The model for rear impacts based on 404 valid records (Table 4) is just non-significant (p = 0.05) and explains only between 3 and 7 percent of the variance (pseudo R^2). Degree of Damage as a variable does not explain any additional variance and was not included in the model after testing. Only gender had a significant effect, with an odds ratio of 3.345 for females of being injured (MAIS1+) versus uninjured (MAIS0) relative to males (p < 0.01).

Regression analysis

Table 4 · Results of the logistical regression analysis for car occupants and rear impact; odds ratios for MAIS1+ relative to MAIS0 (uninjured) used as a reference value

		Regression coefficient B	Standard error	Significance	Exp (B) (Odds Ratio)	95% confidence interval	
						Lower bound	Upper bound
MAIS1+	Age of occupant [years]	0.007	0.011	0.521	1.007	0.986	1.028
	Curb weight of vehicle [kg]	0.000	0.009	0.924	1.000	0.999	1.001
	Initial registration year of vehicle	0.024	0.030	0.426	1.024	0.966	1.086
	Gender: female	1.207	0.378	0.001	3.345	1.595	7.014
	Gender: male (reference)	0					
	Seat position: front passenger	-0.070	0.431	0.871	0.933	0.401	2.170
	Seat position: rear passenger	0.416	1.087	0.702	1.516	0.180	12.754
	Seat position: driver (reference)	0					
	Location: non-built-up area	0.143	0.325	0.661	1.153	0.610	2.180
	Location: built-up area (ref.)	0					

Discussion

The aim of the current study was to shed light on the question of whether females, as car occupants, suffer more serious injuries than men in approximately comparable collisions, independently of the risk of being involved in an accident. The majority of studies of this question come from the USA and it consequently seems justifiable to conduct a similar analysis based on accident occurrence in Germany.

The work presented here has a number of limitations. The limited number of cases in the insurers' accident database (UDB) meant that no odds ratios could be calculated for MAIS3+ injuries, thus restricting the possibility of making comparisons with American studies. The available data also did not make it possible to take account of further characteristics such as belt use or body height. However, by limiting the study to accidents involving collisions between approximately equivalent road users, it was possible to establish a certain level of uniformity across cases in order to address the primary research question more effectively. Compared to studies based on NASS-CDS [4], [5], [6], one advantage appears to be that the current study also included uninjured occupants, or at least occupants who reported no injuries or complaints; it also included individuals who were diagnosed with injuries only after a number of days. It can consequently be assumed that the case material taken from the insurers' accident database (UDB) more completely reflects the actual occurrence of minor injuries.

The results for the odds ratios only show a weak tendency – when the other variables included in the regression analysis are taken into account – for female occupants to be exposed to a greater risk than their male counterparts of sustaining an MAIS2+ versus an MAIS0-1 injury (i.e. no injury or minor injury). When both "all impact types" and front impacts alone are considered, the odds ratios for females of 1.02 and 1.13, respectively, relative to females are considerably lower than in the American studies. In particular, these values are not significant for the "Gender" variable. The seating position in the car has a much stronger effect both for "all impact types" and front impacts: for the passenger seat, the odds ratios for sustaining an MAIS2+ versus an MAIS0-1 injury are 2.09 and 2.44, respectively, compared to the driver's seat. However, among the more recent studies based on NASS-CDS, only

the work of Forman et al. [5] has considered passengers in addition to drivers. One striking finding from the material in the UDB database was that females occupying the passenger seat in cases of front impacts were, on average, 12 years older than their male counterparts. This greater age and the associated higher level of vulnerability could partly explain why the proportion of MAIS2+ injuries is approximately 30 percent higher than in males, as indicated by the descriptive statistics (Table 1). The regression models for "all impact types" and front impacts also identify greater age as a factor that increases the odds ratio. By contrast, a greater curb weight of the occupied vehicle reduces the odds ratio. On average, the curb weight of cars with female occupants was 100 kg lighter than those with male occupants; this tendency is also pointed out by Brumbelow et al. [6] in their work. Among the considered variables, the regression model for rear impacts only indicated a significant effect of gender. In this case, female occupants had the highest of the identified odds ratios at 3.35, a finding that is largely consistent with the results of other studies [2]. However, the small amount of variance explained by the overall model suggests that other factors which were not included in the study have considerably greater effects on injury severities or physical impairments following a rear impact.

The analysis of the national statistics reveals an increasing number of seriously injured occupants, as officially defined, as a proportion of all casualties to occupants in the age group as of approximately 55 years and thus once again confirms the greater susceptibility to injury in older age. For all age groups, the number of seriously injured drivers as a proportion of all female driver casualties is slightly lower than the corresponding proportion among male driver casualties. Among injured occupants over the age of approximately 55 years travelling on the passenger seat or the rear seats, the proportion of those seriously injured is approximately the same for female and male occupants. Given that the official accident statistics do not differentiate between impact types and do not take account of uninjured parties and that the official definition of seriously injured does not correspond directly to MAIS2+ injuries, it is not possible to identify any particularly high risk of women sustaining severe injuries on the basis of the German national data.

Conclusions and recommendations

The current study provides little evidence that females are in general associated with a higher risk of sustaining MAIS2+ injuries than males. Based on the number of cases, the effects calculated for all crashes taken together and for front impacts separately are not statistically significant and are also considerably smaller than those found in American studies. It also raises the question of the extent to which the "Gender" variable contributes to the risk of sustaining MAIS2+ injuries. Alongside the well-known factor of "Age", the results of the regression analysis indicate that, among other things, the weight of the car and the seating position of the occupant, have a considerable influence on the frequency of severe injuries. This might point to a need, for example, to take measures to improve general safety at the front passenger seat.

However this may be, the results provide grounds for conducting more in-depth analyses of German and European accident data, involving large numbers of cases and further variables which might be able to explain injury severity. The question of whether this will point to the necessity of developing a 50th percentile female dummy and using this in all crash tests should first be examined using human body models. It seems logical that such efforts should begin with rear impacts [14], for which, on the one hand – including in the present study – females have a high odds ratio of sustaining MAIS1+ injuries compared to males and, on the other, only one dummy exists that has been certified for test use, namely in the form of a representation of an average male adult.

References

[1] Press release: Norton Announces Bill to Require Gender Equality in Crash Test Dummies. Internet: [https://norton.house.gov/media-center/press-releases/norton-announces-bill-to-require-gender-equality-in-crash-test-dummies], access date: 21st June 2021

[2] Linder, A.; Svensson, M.: Road safety: the average male as a norm in vehicle occupant crash safety assessment. Interdisciplinary Science Reviews; 44:2; p.140-153:2019; https://doi.org/10.1080/03080188.2019.1603870

[3] Evans, L.: Female Compared with Male Fatality Risk from Similar Impacts. Journal of Trauma, Injury, Infection, and Critical Care; 50:2; p. 281-288: 2001

[4] Bose, D.; Segui-Gomez, M.; Crandall, J.: Vulnerability of Female Drivers Involved in Motor Vehicle Crashes: An Analysis of US Population at Risk, American Journal of Public Health; 101:12, p. 2368–2373: 2011

[5] Forman, J. et al.: Automobile injury trends in the contemporary fleet: Belted occupants in frontal collisions. Traffic Injury Prevention; 20:6; p. 607-612: 2019; https://doi.org/10.1080/15389588.2019.1630825

[6] Brumbelow, M.; Jermakian, J.: Injury risks and crashworthiness benefits for females and males: Which differences are physiological? Internet: [https://www.iihs.org/topics/bibliography/ref/2219], access date: 6th October 2021

[7] Kleinert, J. et al.: Geschlechtsspezifische Interventionen in der Unfallprävention. [Gender-related accident prevention] Berichte der Bundesanstalt für Straßenwesen, [Reports by the German Federal Highway Research Institute (BASt)], volume M 179. Bergisch Gladbach: 2006

[8] Bittner, D.: Analyse menschlichen Risikoverhaltens bei Verkehrsunfällen in Mecklenburg-Vorpommern: Ergebnisse einer prospektiven, nicht-interventionellen Beobachtungsstudie. [Analysis of human risk behaviour in traffic accidents in Mecklenburg-Vorpommern. Results of a prospective, non-interventional observational study. Dissertation, Medical Faculty of the Ernst-Moritz-Arndt University, Greifswald: 2010

[9] Federal Statistical Office. Unfälle von Frauen und Männern im Straßenverkehr 2019 [Female and male road traffic accidents 2019]; Internet: [https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Verkehrsunfaelle/Publikationen/Downloads-Verkehrsunfaelle/unfaelle-frauen-maenner-5462407197004.html], access date: 7th October 2021

[10] Viano, D; Parenteau, C.; Edwards, M.: Crash Injury Risks for Obese Occupants Using a Matched-Pair Analysis. Traffic Injury Prevention; 9:1; p. 59-64: 2008; http://dx.doi.org/10.1080/15389580701737645

[11] Federal Statistical Office. Verkehr - Verkehrsunfälle – 2019. [Traffic - Traffic accidents – 2019] Fachserie 8, Reihe 7. German Federal Statistical Office, Wiesbaden: 2021

[12] IBM®: SPSS® Statistics, Version 24.0

[13] Association for the Advancement of Automotive Medicine: Course Training Manual, A specialized Course on Injury Scaling: Uses and Techniques, Introducing The Abbreviated Injury Scale - 2005 Update 2008, Version January 2011. Barrington, Ill.: 2011

[14] Östh, J. et al.: A female head-neck model for rear-impact simulations. Journal of Biomechanics; 51; p. 47-56: 2017; https://www.sciencedirect.com/science/article/pii/S0021929016312568