FREQUENCY AND RISK OF CERVICAL SPINE DISTORTION INJURIES IN PASSENGER CAR ACCIDENTS: SIGNIFICANCE OF HUMAN FACTORS DATA

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Abstract

The parameters: gender, age, height and weight of occupants in passenger cars in relation to cervical spine distortion injuries in traffic accidents have been analyzed on the basis of the VW-Accident-Database.

Occupant gender has proved to be the most important of the human factors parameters under investigation. The risk of suffering neck distortion injuries is about twice as high for women than for men in the database examined.

Regarding the age of occupants, highest risk rates were found in age groups from 18 to 47 years. Risk rates were lower in age groups below and above this range. Occupant height obviously had less effect on the risk of neck distortion injuries. However, apart from side impacts, injury risk slightly increased with increasing height. Occupant weight turned out to be the least important of the parameters investigated.

Effects of the human factors data on cervical spine distortion injuries are modified by different types of passenger cars collisions. With regard to the number of injuries to belted occupants, front impacts rank first, followed by multiple impacts, rear impacts and side impacts. With regard to injury risk, rear impacts rank first, followed by multiple impacts, front impacts and side impacts.

It has been shown that the most frequent occurrences of any parameter may be found in a value range different than the maximum risk of being injured. Therefore, frequency figures regarding occurrences must not be assumed to be equivalent to risk rates.

OBJECTIVE OF THIS PAPER is to evaluate the significance of human factors data regarding the frequency of occurrences and the risk of cervical spine distortion injuries (CSD) in different types of passenger car accidents. The collective term „human factors data" includes the parameters: gender, age, occupant height and weight. The investigation is based on analyses of the Volkswagen-Accident-Database.

Different terms are commonly found in literature. to describe this specific group of injuries: „whiplash", „cervical spine distortion", „cervical trauma", „cervical sprain syndrome", „soft tissue neck injury", „neck sprain" etc. However none of these terms satisfactorily describes the variety and significance of the parameters that are relevant with respect to origin, manifestation, and treatment of these injuries. In the present paper, those injuries to occupants in passenger cars will be called „cervical spine distortion“ (CSD) or „whiplash injury“ or „neck distortion injury“, the location of which is indicated in the database as neck injury and coded as distortion.

Comprehensive reviews of the whiplash phenomenon and of many of the associated parameters have been published by SPITZER et al (1995) and by CROFT (1997).

1. The data base

This investigation is based on analyses of the Volkswagen-Accident-Database. This database contains information on traffic accidents involving personal injury. These data are gathered by the Accident Research Unit of the Medical University of Hannover (MUH) on behalf of the Federal Highway Research Institute (Bundesanstalt für Straßenwesen = BASt). A detailed description of the procedures used in the collection of the data has been published by OTTE (1994). On the average, approximately 800 accidents are investigated annually by multi-disciplinary teams of the Accident Research Unit.

The selection of accidents to be recorded is based on a statistical sampling plan to ensure general validity of the data. However, at least one person must be injured in a traffic accident to trigger a phone call to the MUH and to cause an investigation team to go to the accident scene as soon as possible and commence on-the-spot data collection. Data sets are subsequently completed with results from accident reconstruction procedures, hospitals and many other sources. All information is coded to enable processing by computer, and all information is made anonymous to comply with the German Data Protection Law. Data are then made available commercially, and Volks regularly purchases a copy of the data for a wide variety of user defined analyses (ZOBEL, 1995).

At the moment, the Volkswagen database contains information from 8 150 accidents, involving a total of 20 788 road users and 14 233 vehicles of a wide range of different types. Included are bicycles and motorcycles, passenger cars, trucks, streetcars, construction machinery and even one agricultural combine. The volume of passenger cars is nearly 10 000. No pre-selection of cars is made with respect to type, model or manufacturer. Therefore, the model mix in the database merely reflects the model mix in the accidents in urban and rural areas in and around Hanover.

Although the first accident data in the database date from as far back as 1975, the analysis of frequency and risk of cervical spine distortion is restricted to accidents between 1987 and 1996. During this period 12 011 occupants in 8 061 passenger cars involved in 5 788 accidents were registered.

In this sample, 6 744 occupants (= 56.1 % of all occupants) were not injured. This figure reflects one very important principle of the data collecting system: all road-users who are involved in a documented accident are in fact recorded in the database, even those who have suffered no injury at all. Only because of this principle it is possible to calculate risk rates, i.e. calculate ratios of injured occupants to total numbers of involved occupants in accident situations of a clearly specified type.

Of the total of 12 011 occupants in passenger cars, 1 620 occupants suffered cervical spine distortions. These figures represent a mean injury rate of 13.5 %. However, there was no constant proportion of occupants suffering neck distortion injuries in the decade under investigation. Rather the rate of risk increased from approximately 9 % in 1987 to about 17 % in 1996, as indicated by the mean trend line in Fig.1. Trends were similar for male as well as for female occupants and for the combined group of male and female occupants respectively. The injury severity of 1 583 whiplash injuries (= 97.7 % of the total number) was scaled as AIS=1 on the „Abbreviated Injury Scale" (AAAM,1990).

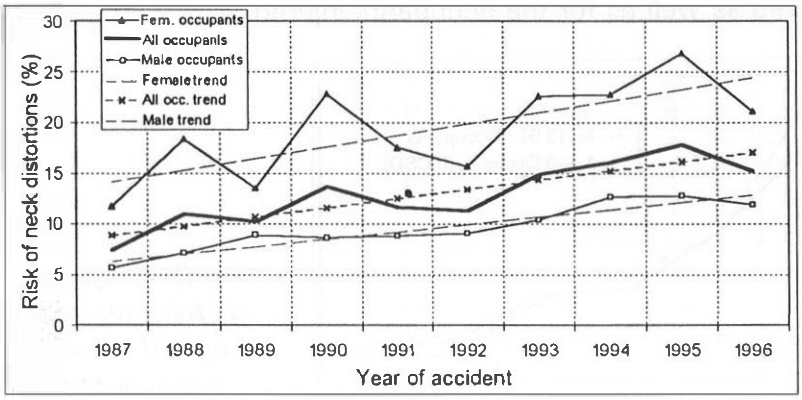

Fig. 1: Percentage of occupants in passenger cars with CSD in different accident years

2. CSD of „all occupants" in relation to human factors data

In an initial series of evaluations, all occupants in passenger cars were included in the analysis without consideration of any additional parameter (for example different collisions types, belt usage etc). Due to a number of „unknown" codes, the numbers of male and female occupants do not add up to the figures given for „all occupants".

2.1. THE GENDER OF OCCUPANTS appeared to be an extremely important parameter in connection with the risk of cervical spine injuries. Despite the preponderance of male occupants involved in passenger car accidents, the number of female occupants suffering from CSD is greater (Table 1). In fact, the proportion of female occupants suffering neck distortion injuries was twice as high as the proportion of male occupants.

Number of:	All occupants	Male occupants	Female occupants	male / female relationship
Occupants involved:	12 011	7 321	4 418	1 / 0.60
Occupants with CSD:	1 620	735	884	1 / 1.20
Injury risk:	13.5%	10.0 %	20.0 %	1 / 2.0

Table 1: Number of occupants involved and number of occupants injured in the Volkswagen Accident Database

As an effect of the unexpectedly large disparity in risk between for men and women, all subsequent analyses were performed both for the total number passenger car occupants as well as separately for male and female occupants.

2.2. THE AGE OF OCCUPANTS has been classified in 10 year groups between the ages of 8 and 67 years in order to analyze the effect of age on neck distortion injuries.

The frequency distribution of the age of involved and of injured occupants in Fig.2 is intended to provide an overview of the frequencies with which the various age groups are represented in the database. Because distributions for the separate groups of male and female occupants where very similar to the distribution for the combined group, curves only for the combined group of occupants were plotted. The diagram reveals clear maxima in the range between 18 and 27 years of age, for the occupants involved as well as for the occupants injured.

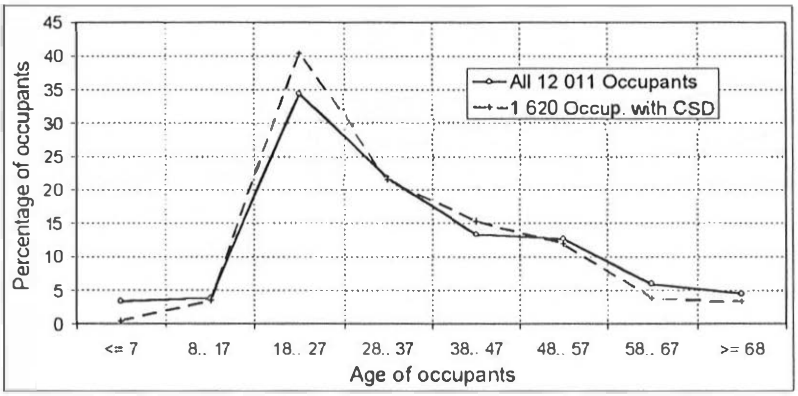

Fig.2: Frequency-distribution of the age of involved occupants and of injured occupants

However, the curves of injury risk in Fig.3 indicate substantially little effect of age in the range between about 18 and 47 years. This is valid for the separate groups of male and female occupants respectively and for the combined group of all occupants with risk figures for the female occupants being twice as high as those for male occupants. Up to an age of 17 and in the age groups above 47 years, the risk of suffering CSD is shown to be less than in the adult range of ages in-between.

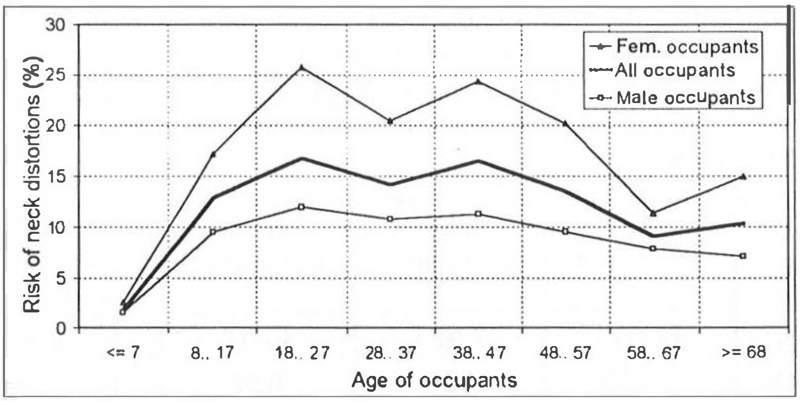

Fig. 3: Injury risk for occupants of different age

There is no indication in the curves for a pronounced increase of risk figures for older occupants, as this is noted in some of the literature.

2.3. THE HEIGHT OF INJURED OCCUPANTS was presumed to be one of the most relevant of the human factors parameters with regard to cervical spine distortion injuries. For an analysis of the relationship between the physical stature of occupants involved and the risk of cervical spine distortion injury, Fig.4 first illustrates the frequency distribution of involvement for occupants of different height. Like ordinary frequency distributions for the physical stature of men and women, the graphs show single peak distribution curves. The difference of approximately 10 cm corresponds almost exactly to the mean difference in height between genders in the German population.

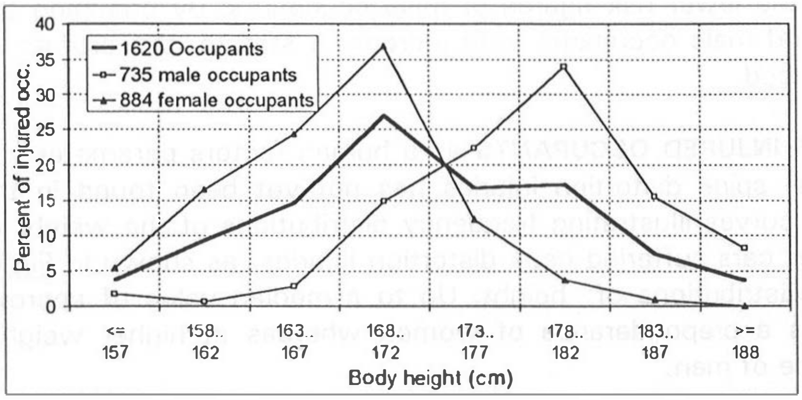

Fig.4: Frequency-distribution of the stature of injured occupants

However, the frequency distribution curve for the combined group also shows one single peak with a position not actually midway between the individual maxima, but within the frequency group for female occupants. This is due to the higher overall number of female occupants injured.

An overall evaluation of relationships between neck distortion injury risk and the physical stature of occupants in Fig.5 reveals the well-known fact that the risk is higher for female occupants compared to the risk for male occupants. This is true in each of the different height groupings. The curves obviously show a minimum risk to smaller occupants, up to a height of about 157 cm. This is in agreement with results which show a lower risk to younger occupants as demonstrated above.

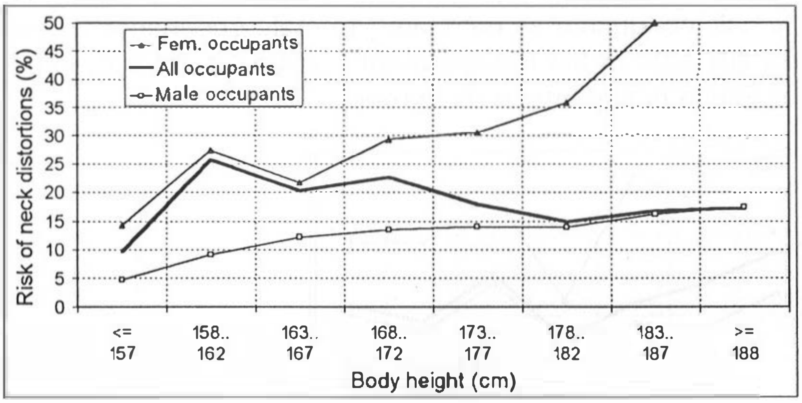

Fig.5: Injury risk for occupants of different stature

For all height groupings above 157 cm, the curves in Fig.5 should be analyzed separately. For female occupants, the risk of cervical spine distortion injury increases significantly with increasing height. Whereas the risk figure is approximately 25 % in the range of about 160 cm, it increases to about 50 % in the range around 185 cm. For male occupants, the increase in risk with greater height is also valid, although less pronounced.

In contrast, the risk of suffering cervical spine distortion injuries of the combined group appears to decrease with increasing height, as indicated by the solid line in Fig.5. However, this decrease must be characterized as an artifact that can be regarded as a side effect of the different risk values for male and female occupants on one hand and the different proportions of male and female occupants in different height ranges on the other. In lower height ranges, the mean risk curve follows the higher risk for female occupants. In the higher stature ranges, the mean risk follows the lower risk figures of male occupants. By changing the proportion of female and male occupants with increasing stature, the artifact of decreasing risk is produced.

2.4. THE WEIGHT OF INJURED OCCUPANTS as a human factors parameter and any effects on cervical spine distortion injuries has not yet been found in the literature. The type of curves illustrating frequency distributions of the weight of occupants of passenger cars suffering neck distortion injuries, as shown in Fig.6, is very similar to the distributions of height. Up to a median value of approximately 70 kg, there is a preponderance of women whereas at higher weights there is a preponderance of men.

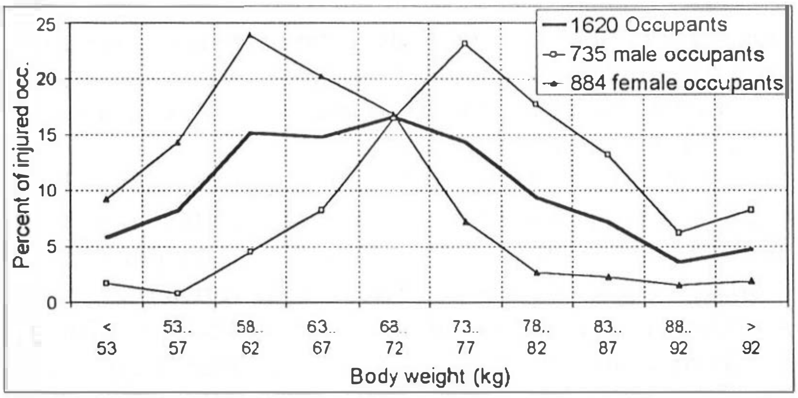

Fig.6: Frequency-distribution of the weight of injured occupants

The risk of cervical spine distortion injuries in relation to weight (Fig.7) was found to be higher for female occupants as compared to male occupants. For each weight class, risk values are least in the lowest weight group (< 53 kg), because of the high proportion of young occupants in this group.

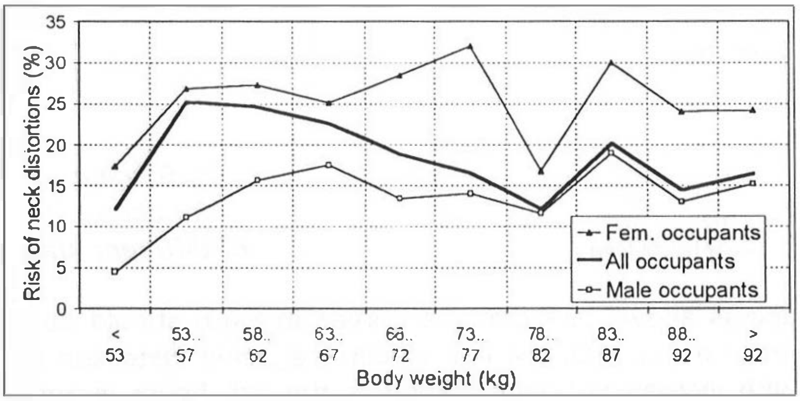

Fig.7: Injury risk for occupants of different weight

Because of the low risk figures for female occupants in the weight range from 78 to 82 kg in comparison with risk figures in the higher and in the lower weight classes, there appears to be poor consistency in the results for female occupants. Inasmuch as there were 21 injured female occupants in this class in the database, the inconsistency cannot be attributed only to low number of cases. This break in continuity is not yet understood. Therefore, it must be noted that there is no clear relationship between weight and the risk of CSD injury for male and female occupants in weight classes above about 60 kg.

The resulting curve for the combined sample of male and female occupants shows the artificial effect of changing proportions of men and women in weight classes with increasing weight. There seems to be no purpose to be achieved in any attempt to carry out a uniform interpretation of these combined data.

3. CSD in relation to human factors data in different types of collision

In comparing effects of human factors parameters in different types of collisions, evaluations were limited to belted occupants in order to achieve the greatest possible homogeneity in occupant groups. For the most part, different types of passenger car accidents are characterized as frontal impacts, side impacts etc. depending on the location of principal vehicle deformation. However, in many accidents the event is not yet over at the end of the first impact. On the contrary, approximately 23.5 % of all occupants in passenger cars in the database were involved in at least one additional impact. About 5.6 % of the occupants experienced even more than one subsequent impact. A distinction between single impact accidents and multiple impact accidents is important whenever a specific injury is sought to be attributed to a specific impact. Correlations of this type may be difficult in multiple impact accidents.

With respect to cervical spine distortions, the number of belted occupants involved in different collision types and sustaining CSD is shown in Table 2.

Item:	Single front impacts	Single rear end impacts	Single side impacts	Single rollover	Multiple impacts
All occupants					
Total number	518	218	161	15	454
Identified male occupants					
All male occ.	231	87	68	7	215
Age	231	86	68	7	215
Body height	206	70	61	7	215
Body weight	207	77	60	7	215
Identified female occupants					
All fem. occ.	287	131	93	8	239
Age	285	129	93	8	239
Body height	260	120	84	8	239
Body weight	260	121	84	8	239

Table 2: Total number of belted occupants and number of occupants with identification of age, height and weight sustaining CSD in different types of collisions

No classification of multiple impacts according to uniform impact sequences was made in order to obtain an adequate number of cases in each group under investigation. For the same reason, no classification of single side impacts was made, although classification according to near side occupants and far side occupants could be justified. The total number of occupants involved in rollover accidents was too small for any evaluation of the effects of human factors parameters on the frequency and risk of neck distortion injuries.

Furthermore, human factors data are not available in the database for some of the occupants and injured occupants involved. This lack of data is the reason for different numbers of cases in table 2 and 3.

Some preliminary evaluations revealed a large scattering of results according to low number of cases, while maintaining identical groupings of the human factors data as shown in the previous section. In order to reduce this scatter, all of the following evaluations were made with reduced numbers of groupings for age, height and weight.

Interactions of occupant gender on the one hand and different collision types on the other may be seen in Table 3. Obviously, the frequency as well as the risk of cervical spine distortions are different in various types of collisions.

	Single front impacts	Single rear end imp.	Single side impacts	Single rollover	Multiple impacts
Number of involved occupants					
All occupants	4 395	860	1 566	67	2 148
Male occupants:	2 692	503	911	47	1 332
Female occupants:	1 651	340	639	19	801
Number of occupants with cervical spine distortions					
All occupants injured:	518	218	161	15	454
Male occupants:	231	87	68	7	215
Female occupants:	287	131	93	8	239
Risk of CSD (= number of occupants injured / number of occupants involved [%])					
All occupants:	11.8 %	25.3 %	10.3 %	22.4 %	21.1 %
Male occupants:	8.6 %	17.3 %	7.5 %	14.9 %	16.1 %
Female occupants:	17.4 %	38.5 %	14.6 %	42.1 %	29.8 %
Risk-ratio (fem./male)	2.0	2.2	1.9	2.8	1.8

Table 3: Number of belted occupants and number of belted occupants with cervical spine distortion injuries

The lowest risk of cervical spine distortion injuries (regardless of gender) has been found in side impacts (10.3 % of all belted occupants involved sustained CSD), the highest risk has been identified in rear end impacts (25.3 %). However, these figures do not reflect the number of injured occupants in the respective impact types. The greatest frequency of injuries occurred in frontal impacts (518 belted occupants), while the number of occupants being injured in rear end collisions was 218 only. These figures once again confirm that the frequency of occurrences must not be taken as equivalent to the risk of suffering injuries.

3.1. Effects of **GENDER** on the risk of neck distortion injuries can best be explained by the last line in Table 3: In all collision types, the risk of being injured was 1.8 to 2.2 times as high for female occupants as for male occupants (the ratio of 2.8 for rollover was not considered because of an insufficient number of cases).

3.2. Effects of **AGE OF OCCUPANTS** with respect to the risk of neck distortion injuries for various age groups (Fig.8) indicate that the lowest risk exists in the age group up to 17. This is valid for male and female occupants respectively and for all impact types under investigation. In the higher age groups, age appears to have little effect on the risk of injury for male occupants in all impact types, apart from rear end collisions, in which a slight increase in the risk of injury can be seen with increasing age. In summary, the risk of injury risk for male occupants is higher in rear end impacts and in multiple collisions than in frontal or in side impacts.

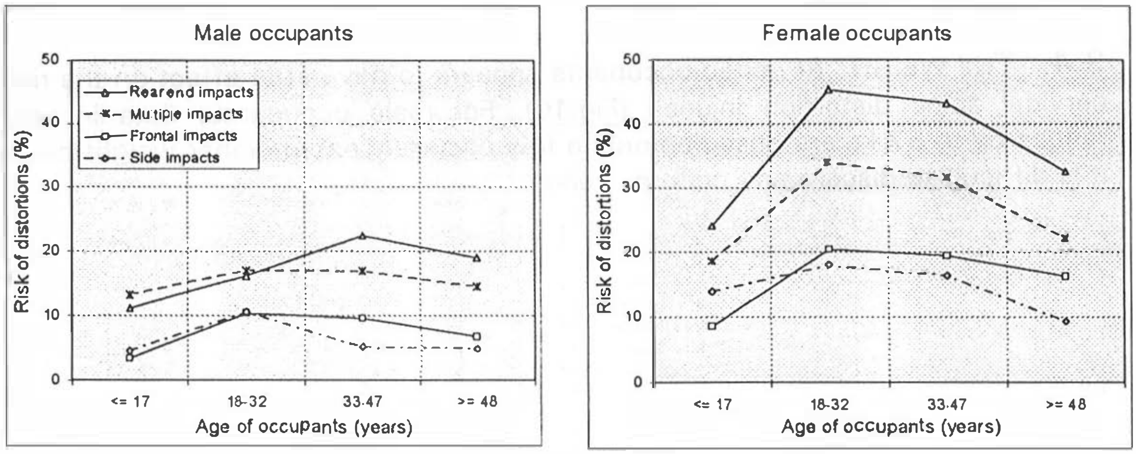

Fig.8: Injury risk to belted occupants of different age

For women alone, the risk of neck distortion injury appeared the highest in the age group from 18 to 32 with the pattern of risk showing a decreasing trend with increased age. However, compared to the results for male occupants, there is a pronounced distinction between rates of risk in different types of impact.

3.3. **HEIGHT** appears to have some effect on cervical spine distortion injuries sustained by belted occupants in passenger cars (Fig.9). Because there was an insufficient number of occurrences for male occupants in the lowest height class and with respect to female occupants in the tallest height class, no data were entered into Fig.9 with respect to these parameters.

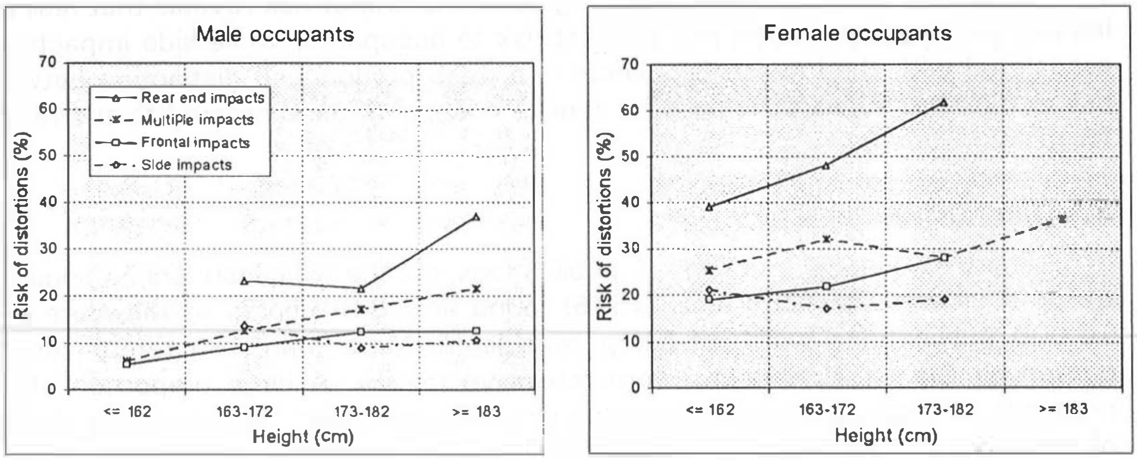

Fig.9: Injury risk to belted occupants of different physical stature

With respect to male occupants, the curves in Fig.9 demonstrate that the highest risk exists in rear end impacts. In multiple collisions and in frontal impacts, a steadily increasing risk can be identified with increasing height. In side impacts only, no effect on the rate of risk attributable to height could be identified.

The risk of cervical spine distortion injury is obviously affected more by height with respect to female as opposed to male occupants. In addition, risk values associated with female occupants are affected more by type of impact than the rate of risk for male occupants. However, no marked effects could be found in side impacts.

3.4. THE WEIGHT of belted occupants appears to have little effect on the risk of cervical spine distortion injuries (Fig.10). For male occupants, data in weight ranges up to 57 kg are based on only a few occurrences. In higher weight classes, it is difficult to discern any uniform trend.

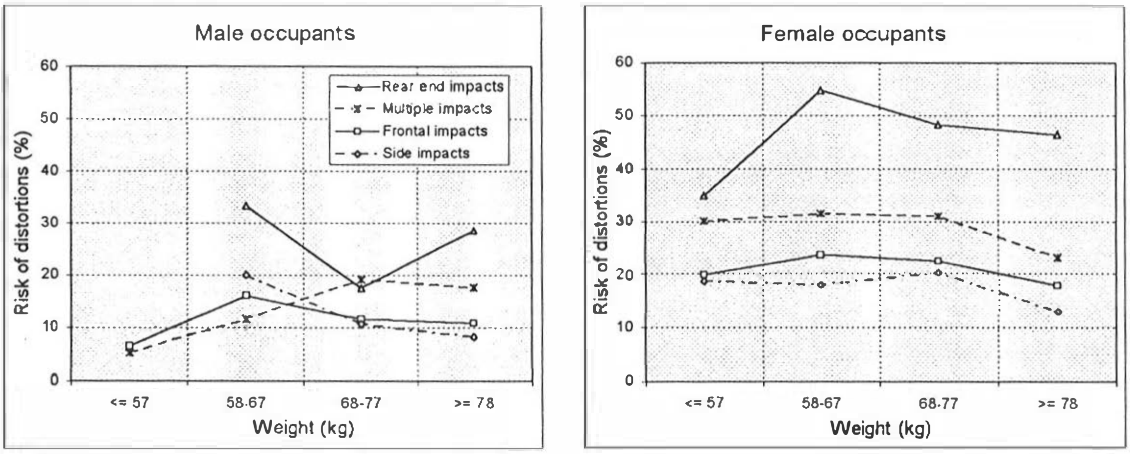

Fig.10: Injury risk to belted occupants of different weight

For belted female occupants, as the horizontal course of the risk rate curve indicates, weight has virtually no effect on the risk of neck distortion injuries. However, there appears to be slight but decreasing effect in the weight group above 78 kg for all types of impact.

A ranking of impact types with regard to the rate of risk reveals that rear end impact are associated with the greatest risk to occupants, while side impacts are associated with the lowest risk. There is a more pronounced distinction between risk in different types of impact for female occupants as compared to the results for male occupants.

4. Discussion

There is a large number of publications on the whiplash phenomenon in traffic accidents. SPITZER et al (1995) found only 346 papers of the more than 10 000 publications worth of being considered. More than 480 references are quoted by CROFT (1997) in a comprehensive review. A large proportion of the papers is restricted to rear end impacts involving passenger cars, because the risk of cervical spine distortion injuries is frequently argued to be exceptionally high in accidents of this type. However, as a result of conceptual variability in different analyses, a comparison of results is usually impeded.

4.1. The gender effect, i.e. higher risk of CSD injury for female occupants as opposed to male occupants has been reported many times. Even the conclusion that *„generally ... neck injury frequency among women was up to twice as high as among men"* can be found as early as 1969 (KIHLBERG). However, the differences vary in different reports. To date, specific reasons for the male-female-variance in injury risk have not been established. Many concepts and hypotheses on this matter have been advanced in the literature.

Some attempts have been made to attribute the differences in injury risk to anatomical and physiological parameters. With reference to data from the U.S. Air Force from 1963, STATES et al (1972, p.2851) stated: *„Male necks are larger in circumference than are female necks"*. This statement was based on the ratio of head volume to cross sectional area of necks: *„For the 50^{th} percentile male, it is 1:135 and for the comparable female it is 1:151. The ratio is determined by the formula: Ratio = (head circumference)^3 / (neck circumference)^2. This ratio quantitates the observation that females have smaller necks relative to head size"*.

Basic physical characteristics of the neck have been measured by FOUST et al (1973) on 180 volunteers. The range of motion of females was found to be greater than that of men. Average neck muscle reflexes were slower with males. Strength tests revealed that males are on average stronger than females in both flexor and extensor strength.

None of these characteristics has ever been demonstrated to be significant with regarding respect to injuries to occupants of passenger cars. KRAFFT et al (1996, p.1430) even ask: *„Are women more vulnerable to AIS1 neck injury due to anatomical reasons or do they have a worse sitting position in the car-seat than men do?"*

Gender-related differences in tissue properties and in physical parameters of ligaments and tendons are sometimes cited in discussions. These differences obviously were to be found in the higher sensitivity of women to impacts as witnessed by an increased propensity to bruising. Concrete findings and quantitative supporting data are still lacking.

One completely different reason is put forward in a US study which notes that: *„women tend to sit farther forward in their seats than men, their heads move farther to the rear in a crash before reaching a head restraint"* (IIHS, 1995, p.10). And SPITZER et al (1995, p.19-S) quote: *„Another possibility is that women may be more inclined than men to file an insurance claim for whiplash"*. No further specifications to these hypotheses are available thus far.

OTTE et al (1997, S.272) refer to: *„some difference of sex-specific accident framework conditions. Women suffer neck distortions in small or lighter cars respectively more frequently than men"*. In addition, LUNDELL et al (1998) point on some gender specific preferences regarding occupant posture, seating position, variations in individual restraint adjustment etc.

To summarize the different hypotheses on the gender effect: none of the quoted parameters appears capable of providing a plausible and comprehensive rationale for the higher risk to female occupants as compared to male occupants in passenger car accidents.

4.2. Age as a parameter with some significance to CSD injury has been analyzed in few publications. NASS data from 1988 to 1994 (NASS = National

Accident Sampling System) show an increase in injury rate with increasing age of passenger car occupants: Between 15 and 34 years: 27.5 %, between 35 and 54 years: 32.6 % and for 55 and over: 34.4 % (NHTSA,1996). This sample includes male and female front outboard occupants involved in tow-away rear-end impacts. In general, the injury rate for females was slightly higher than for males (34.0 % vs. 29.0 %). No information is available about belt usage.

For children and adolescents, lower injury risk rates are reported. For instance: *„Children were less prone to neck injuries than adults, but otherwise age had no influence on the incidence of such injuries"* (LÖVSUND et al, 1988, p.324). Very similar is the statement: *„children up to ten years of age are at 1/6 the risk of injury as adults" (OMMAYA et al,1982).* Regarding adults only, CROFT summarizes: *„As age increases beyond the 30s, the risk of injury generally increases. This is probably due to a reduced range of motion, slower muscle reflexes, decreased muscular strength, and the fact that injured tissues generally heal slower in older persons. However, some authors have not observed great variations in injury risk with respect to age"* (CROFT,1997, p.54).

4.3. The height of occupants has been analyzed regarding its effect on CSD injuries only recently. Fig.11 provides insight into data contained in this paper as compared to data from NHTSA (1996) and LUNDELL et al (1998). Differences in the kind of data should be taken into consideration: *„The data is based on a subset of 2050 belted occupants of Volvo cars in a rear end impact, and seated in an outer seat equipped with a head restraint"* (LUNDELL et al,1998, p.3). The NHTSA data *„are based on NASS weighted data of tow-away crashes. Non-contact AIS 1 neck injuries (whiplash) to front outboard occupants have been identified from impacts where the primary damage was to the rear of the vehicle."* (NHTSA, 1996, p.15)

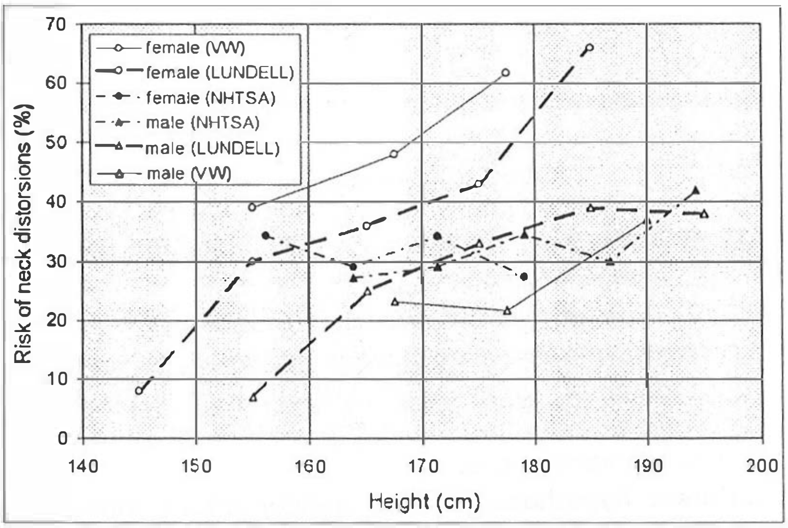

Fig.11: Injury risk data to male and female occupants of different height (rear-end impacts only)

In general, it is difficult to discern a uniform trend for a correlation between height and the risk of CSD injuries. Results of LUNDELL et al and VW reveal an increasing tendency with increasing height and an overall higher risk for female occupants. The gender effect is less pronounced in the Volvo data. According to the NASS data, on the other hand, the trend for male occupants points to an increasing injury rate with increasing height; the trend for female occupants is just the opposite, but with a flatter slope (NHTSA, 1996, p.17).

4.4. Weight of occupants as a parameter in relation to the risk of cervical injury appears to be very rare in the literature. CROFT (1996) quotes this item in combination with recommendations that children ride only in approved child safety seats. No quotations have been found so far regarding cervical spine distortion injury risk and weight for adults. Only KRAFFT et al (1996,p.1430) point to the hypothesis, that women could be *„more vulnerable to AIS1 neck injury because they in general weigh less than men, and therefore reach a higher velocity before the torso is thrown into the seat-belt"*. However, this hypothesis would appear to be disproved by the data in Fig.10.

5. Summary

1. It has clearly been shown that the most frequent occurrence for any analyzed parameter may be found in a different value range of this parameter than with respect to the maximum risk of being injured. For example, the frequency distribution of the age of the injured occupants reveals a distinct peak in the range from 18 to 27 years, while the risk of cervical spine distortion injuries is obviously not affected at all by the age parameter in the range from 18 to 47 years.

2. In the VW database, the risk of neck distortion injury is roughly twice as high for women as for men. This parameter has been identified to be the most important one of a large number of variables (including car types), which where evaluated in a comprehensive study of whiplash in rear-end collisions (TEMMING, 1997). Basically, this is conform to many similar statements in the literature. However, to date few consequences have been drawn from this factual knowledge. Although many different hypotheses regarding the origin of these differences have been published, no clear rationale can be given at this time.

Slight differences in the risk ratio of female to male occupants have been identified in different collision types.

3. The obvious differences in the injury risk to male and female occupants have additional effects on all those variables that are in any way associated with gender. This has been demonstrated in particular with height and weight, where artifacts may lead to faulty conclusions to the degree that the gender effect is ignored.

4. However, the gender effect is even important with respect ratings of motor vehicles or ratings of head restraint systems, whenever vehicle occupancy with male and female passengers is different. For example, the ratio of belted male to female occupants in passenger cars of the GOLF-class was found to be in the range of 1.4 : 1 in the VW database as compared to 4.3 : 1 in the luxury car class. Any ratings without consideration of the gender effect will therefore indicate higher safety qualities than appropriate, whenever the share of male occupants is higher than medium.

5. Regarding the significance of occupants age, it appears that the risk of cervical spine distortion injury is greater across a broad range of age from about 20 to 50 years than in the lower and higher age groups.

6. Height proved to be related to marked effects on the risk of neck distortion injury to female occupants; the effects are less pronounced for male

occupants. No effect of height on the risk of injury could be identified in side impacts.

7. No uniform effects of occupant weight on the risk of cervical spine distortion injuries could be identified.

8. For several reasons, the figures shown in this paper do not precisely reflect the overall risk of cervical spine distortion injury in all traffic accidents. On the one hand, the VW database includes only accidents in which at least one person was injured. Accordingly, all accidents with property damage only, i.e. with uninjured occupants, are not recorded in the database. Therefore, it is possible that all risk figures regarding neck distortion injuries are too high with respect to all accidents. On the other hand, the fact must be considered that some subjects suffering neck distortion injury do not appear to be injured at the accident scene. Data referred to by SPITZER et al (1995) indicate, that the onset of neck pain did not occur until 12 hours after the collision in about 22 % of involved occupants. In addition, human factors data of uninjured occupants may be not as rigorously documented as data pertaining to injured occupants. Therefore, the basic figure (i.e. the total number of involved occupants) used in calculating risk values may be too low.

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