CAR-PEDESTRIAN ACCIDENTS IN GOTHENBURG DURING TEN YEARS

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ABSTRACT

The purpose of this study was to investigate changes in the incidence and consequences of car-pedestrian accidents in urban traffic during a ten year period. We compared the type and severity of the injuries recorded at the hospitals in Gothenburg during the periods 1983-1986 and 1993-1996. We focused on accidents where the pedestrian was hit by the front part of a car or taxi. The circumstances of the accidents and the impact speed were deduced from police reports. The shape and dimensions of the impacting structures were determined from standardized drawings of the vehicles.

Comparing the two time periods, the number of accidents reduced by 38%. The average ISS reduced overall, especially in children (50%) and the elderly (39%). The occurrence of serious, severe, critical, and fatal injuries (AIS3+) decreased in all regions of the body, and also the distribution of the injuries changed. Serious or more severe injuries became more frequent in the head and chest and less frequent in the knee and lower leg during the later period. The percentage of the injured with severe fractures of the knee or lower leg decreased significantly.

The main reasons for these differences are probably a reduced car-traffic intensity and a reduced traffic speed within the central part of the city. However, such changes cannot explain all the differences, and we conclude that changes in car design between the two time periods may have an influence too.

THE NUMBER OF PEDESTRIAN FATALITIES in car-pedestrian accidents has decreased in most motorized countries (1), and so has the number of pedestrian fatalities per million cars. These changes may be due to an improved infrastructure of the road traffic system and changes in car design. However, pedestrian casualties are still a major concern in traffic accident safety in many countries. Consequently, the European Experimental Vehicles Committee (EEVC/WG10 & WG17), the National Highway Traffic Safety Administration (NHTSA), the International Standard Organization (ISO/TC22/SC10/WG2), and the International Harmonized Research Activity (IHRA) have been conducting studies to propose a pedestrian test procedure reflecting real-world pedestrian accidents.

Their ongoing efforts have been focused on sub-system test methods and regulations for the assessment of the aggressiveness of car-front structures using the available pedestrian accident data of the 1980's. Unfortunately, the car-front shape has changed drastically during the last decade. Thus it is necessary to clarify the injury pattern in pedestrians involved in accidents of more recent years. Regarding this point, one way to capture the situation of car-pedestrian accidents is not only to analyze the injury pattern suffered in accidents during a specific period, but also to look at two different time periods to compare car-pedestrian accidents as of now and in the past.

During the last two decades, many investments were made in Gothenburg (450,000 inhabitants) in order to reduce the number and severity of traffic accidents. As a result, the number of fatally and severely injured road users of all categories has decreased [(2)]. These changes may be due to an improved infrastructure of the road traffic system and changes in car design.

The Traffic Injury Register (TIR) in Gothenburg, Sweden has been collecting the injury data of pedestrian-car accidents for more than 15 years. TIR was established in 1978 in order to compensate for deficiencies in official traffic accident statistics, to facilitate diagnosis and therapy for the injured, and to create a foundation for the study of injuries and their sequelae after traffic accidents [(3)]. TIR is a hospital-based organization cooperating with the Traffic and Public Transport Authority in Gothenburg in order to achieve an optimal planning of traffic safety investments in general. TIR collects data on the accidents' circumstances and injuries from the main hospitals in Gothenburg. TIR also has access to the police reports describing the accidents.

The purpose of this study was to investigate if there were changes in the incidence and consequences of car-pedestrian accidents in urban traffic during a ten year period, and if so, to what extent these changes were related to changes in traffic intensity and car design.

MATERIAL

Hospital data collected by TIR, on pedestrians hit by cars or taxies , were matched with accident data from police reports for the two time periods of 1983-1986 and 1993-1996. The number of cases was 372 and 229, respectively (Table 1). Car-front shapes were determined in 167 (45%) of the cases in 1983-1986 and 99 (43%) of the cases in 1993-1996. The police reports included the type of the car and its travel speed. The travel speed estimated by the driver, deduced from the police reports, was known in 145 (39%) of the cases in 1983-1986 and in 76 (33%) of the cases in 1993-1996. Both the car-front shape and the travel speed were deduced in 109 (29%) of the cases in 1983-1986 and 64 (28%) of the cases in 1993-1996.

Table 1 - Outline of the database (The number of pedestrians by different information)

Data	Number of pedestrians	Number of pedestrians; where the body shape of the car is deduced from the police report	Number of pedestrians; where the travel speed is deduced from the police report	Number of pedestrians; where the body shape of the car and the travel speed are deduced from the police report
83-86	372	167	145	109
93-96	229	99	76	64

METHODOLOGY

THE SEVERITY OF THE INJURIES was coded according to AIS-80 [(4)] for pedestrians injured during 1983-1986 and according to AIS-85 [(5)] for pedestrians injured during 1993-1996. In this study, the conversion of the earlier AIS-grade for unification with the later AIS-grade was done in order to compare the occurrence of injuries in specific body regions during the two time periods. Thus, injuries during the earlier period were re-coded according to AIS-85. These body regions were the head, chest/thoracic spine, abdomen/lumbar spine, pelvis/hip joint, thigh, knee and lower leg*. There were no differences in AIS between AIS-80 and AIS-85 for head, pelvis/hip joint, thigh and lower leg, however there were some differences for chest/thoracic spine, abdomen/lumbar spine and knee (Table 2). For knee for example, there were 11 cases which were AIS3 by AIS-80 which were re-coded as AIS2 by AIS-85. The rest of the body regions which were not re-coded by AIS-85 were face, neck, shoulder/arms and ankle joint/foot.

Table 2 - AIS conversion from AIS-80 to AIS-85 for the injuries in 1983-1986

Region		AIS conversion AIS80 → AIS85	Number of injury	Distribution of injury(%)
Chest, Thoracic spine	Changed AIS	AIS1 --> AIS2	4	5.0%
		AIS2 --> AIS3	8	10.0%
		AIS5 --> AIS6	1	1.3%
	Total (Changed AIS)		13	16.3%
	No changed AIS		67	83.8%
	Total		80	100.0%
Abdomen, Lumbar spine	Changed AIS	AIS3 --> AIS2	3	6.3%
		AIS3 --> AIS4	1	2.1%
		AIS4 --> AIS2	2	4.2%
		AIS4 --> AIS3	1	2.1%
	Total (Changed AIS)		7	14.6%
	No changed AIS		41	85.4%
	Total		48	100.0%
Knee	Changed AIS	AIS3 --> AIS2	11	8.0%
	Total (Changed AIS)		11	8.0%
	No changed AIS		126	92.0%
	Total		137	100.0%

The type and location of injuries were coded according to the International Statistical Classification of Disease (ICD). The Injury Severity Score (ISS) [6] was calculated from the AIS80-grades during the first period and from the AIS85-grades during the second period. The ISS-scores were not re-calculated in cases with the different AIS-grades of AIS80 and AIS85.

THE RELATIVE FREQUENCY OF INJURY is used to describe the distribution of injuries by different body regions. The formula is shown below:

$$\text{Relative frequency of injury (\%)} = \frac{\text{Number of given injuries by given AIS level}}{\text{Number of all injuries by given AIS level}} \times 100$$

THE OCCURRENCE OF INJURY is used to describe the frequency of injuries by different body regions. The formula is shown below:

$$\text{Occurrence of injury (\%)} = \frac{\text{Number of pedestrians who sufferd a given injury}}{\text{Number of all pedestrians}} \times 100$$

(It was 372 in 1983-1986 and 229 in 1993-1996)

When comparing the relative frequency or occurrence of injury, we classified the injuries by non-minor (AIS2+) and severe (AIS3+) injury. The AIS2+ classification is important for it includes all injuries except minor injuries. Moreover, AIS2+ is used as the errors due to the use of different AIS-grades seem to be minimized as shown in Table 2. There was only one case that the AIS-grade was changed between AIS1 and

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* The lower leg indicates the region between knee and ankle joint in this study.

other AIS, this was four injuries in chest/thoracic spine. The classification of AIS3+ is used for the fatality rate which is high from AIS3. However when classifying the injuries by AIS3+, the number of injuries is sometimes small, and for this reason only the classification of AIS2+ is used in some cases.

THE TRAVEL SPEED was used in this study since the impact speed was not available. However, the travel speed has a good correlation to the impact speed [7].

THE CAR-FRONT SHAPE was determined from pictures available from Autograph Bilfakta Company, Helsingborg, Sweden. The bonnet leading edge* angle and the bonnet edge height were used to define the car-front shape. All cars in the database were classified by two body shapes, V-shape and Pontoon.

V-shape : The bonnet leading edge angle is less than 60 degrees, or the bonnet edge is lower than 0.7 m.

Pontoon : The bonnet leading edge angle is equal to or more than 60 degrees, and the bonnet edge is equal to or higher than 0.7 m.

THE TWO-TAIL STUDENT'S T-TEST was used to check the statistical significance level between the average values in two time periods, such as average ISS. The chi-square test was used to check the statistical significance level between the percentages in two time periods, such as relative frequency and occurrence of injuries.

RESULTS

The number of injured pedestrians decreased 38% between the two time periods, and the number of injuries per individual did not change (Table 3). However, the injury severity score (ISS) was reduced and the relative frequency and occurrence of injuries in different regions of the body changed. There was a reduction of the travel speed and the car-front shape changed between the two time periods, which seems to be related to the injury severity in different regions of the body. This will be described in detail in the following paragraphs.

THE AGE DISTRIBUTION OF PEDESTRIAN changed. The proportion of the elderly decreased from 33% to 21% and that of children and adults increased from 20% to 25% and 47% to 54% respectively (Table 3).

THE AVERAGE ISS (Table 4) decreased from 8.9 to 5.7 between the two time periods for all the injured (P<0.01). The average ISS decreased significantly from 9.6 to

Table 3 - Number of pedestrians by age and injuries by all ages

Data / age	Number of pedestrians 0-15	16-59	60-	Total	Number of injuries	Number of injuries per individual
83-86	74 (20 %)	175 (47 %)	123 (33 %)	372	1108	3.0
93-96	58 (25 %)	122 (54%)	49 (21 %)	229	656	2.9

Table 4 - Average ISS by age

Age \ Data	83-86 (AIS80) Average ISS	N	93-96 (AIS85) Average ISS	N	Average ISS decrease (%)
0-15	9.6	74	4.9	58	* 49%
16-59	6.9	175	5.6	122	19%
60-	11.3	123	6.9	49	** 39%
All ages	8.9	372	5.7	229	** 36%

* P<0.05, ** P<0.01

* The bonnet edge height is determined according to the EEVC pedestrian test method.

4.9 for children ($P<0.05$) and from 11.3 to 6.9 for the elderly ($P<0.01$). The average ISS of the different age groups became more equal during the later period.

THE RELATIVE FREQUENCY OF NON-MINOR (AIS2+)/SEVERE (AIS3+) INJURIES BY BODY REGIONS is shown in Figure 1. For severe (AIS3+) injuries , the relative frequency of head and chest injuries increased from 15% to 28% and from 10% to 29%, respectively ($P<0.01$). The relative frequency of severe knee and lower leg injuries decreased from 17% to 4% ($P<0.01$) and 20% to 10% ($P<0.01$), respectively. For the non-minor injuries (AIS2+), the distribution did not differ so much between the two time periods, except for the ankle joint/foot of which the relative frequency increased from 3% to 7% ($P<0.05$) .

The relative frequency of non-minor (AIS2+) injuries by body regions by age is shown in Figure 2. The relative frequency of head injury increased in adults ($P=0.12$) and the elderly ($P=0.18$) and decreased in children ($P=0.12$). The pelvis/hip joint was more frequently injured in the elderly compared with the other age groups. The relative frequency of chest injury increased ($P<0.05$) in children.

THE OCCURRENCE OF NON-MINOR (AIS2+)/SEVERE (AIS3+) INJURIES BY BODY REGIONS is shown in Table 5. The occurrence of severe knee and lower leg injuries decreased significantly ($P<0.01$) but that of severe head and chest/thoracic spine injuries did not change significantly. For the non-minor injuries (AIS2+), the occurrence of ankle joint/foot injury increased ($P<0.01$) and that of chest/thoracic spine and abdomen/lumbar spine injuries decreased ($P<0.05$). The occurrence of specific non-minor (AIS2+)/severe (AIS3+) injuries by body regions is shown in Table 6.

Head: Cerebral concussion was the most frequent injury during the two time periods in non-minor (AIS2+) injuries. However in severe (AIS3+) injuries , skull fracture was the most frequent injury in 1983-1986 and intracranial injury was the most frequent in 1993-1996.

Face: The fracture of the nose/mandible/face was the most frequent injury during the two time periods.

Neck: The fracture of the cervical spine was the most frequent injury during the two time periods.

Shoulder/Arms: The fracture of the shoulder/arms was the most frequent injury during the two time periods.

Chest/Thoracic spine: The fracture of the rib(s) or sternum was the most frequent injury during the two time periods by AIS2+. In 1993-1996 by AIS 3+, the cardiac or lung injury was the most frequent injury.

Abdomen/Lumbar spine: The internal organ injury was the most frequent injury during the two time periods. In AIS2+, the occurrence of fracture of the lumbar spine decreased ($P<0.05$).

Pelvis, Hip joint: The fracture of the pelvis was the most frequent injury during the two time periods by AIS2+ and also in 1983-1986 by AIS3+. The occurrence of fracture of the pelvis decreased significantly by both AIS2+ and AIS3+. Therefore in 1993-1996 by AIS3+, the fracture of the collum femur/trochanter occurred more frequently than fracture of the pelvis. The cause of this change is discussed later.

Thigh: The fracture of the thigh (middle part of femur) was the most frequent injury during the two time periods by both AIS2+ and AIS3+.

Knee: The fracture of the knee (lower part of femur, patella or upper end of tibia or fibula) was the most frequent injury during the two time periods by both AIS2+ and AIS3+. In both AIS2+ and AIS3+, the fracture of the knee decreased significantly ($P<0.05$ by AIS2+ and $P<0.01$ by AIS3+). Distortion of the knee was the second most frequent injury in AIS2+ but there was no significant decrease between the two time periods.

Lower leg: The fracture of the lower leg (shaft of tibia or fibula) was the most frequent injury during the two time periods by both AIS2+ and AIS3+. In both AIS2+ and AIS3+,

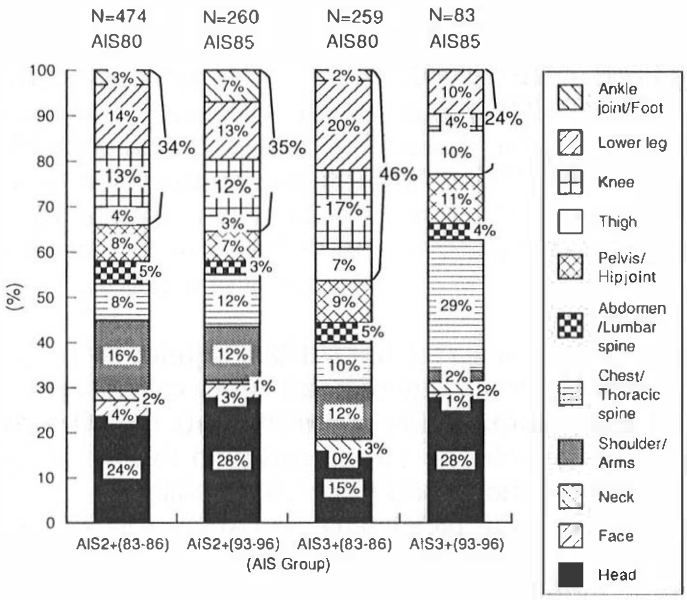

Fig. 1 - Comparison of relative frequency of injuries in different body regions by AIS 2+ and AIS3+ between 1983-1986 and 1993-1996

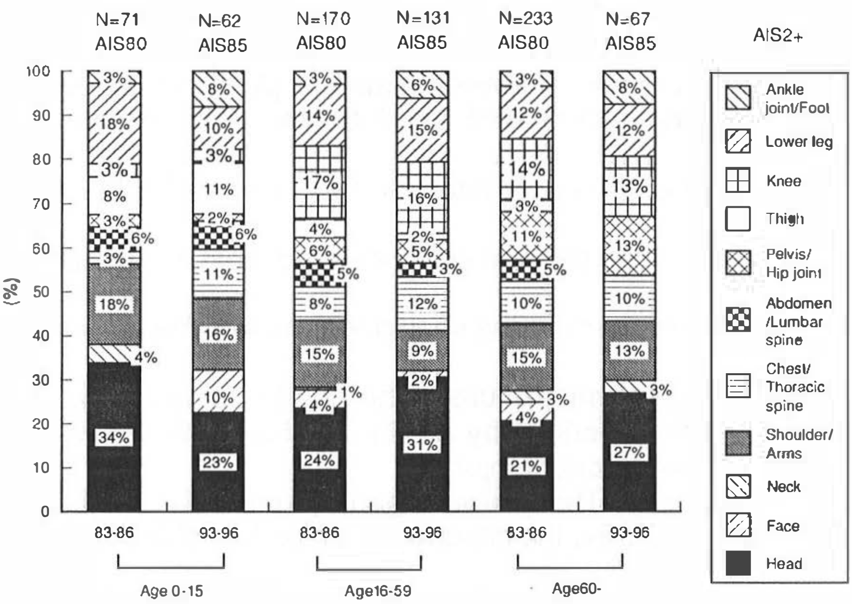

Fig. 2 - Comparison of relative frequency of injuries in different body regions by age in AIS 2+ between 1983-1986 and 1993-1996

the fracture of the lower leg decreased significantly (P<0.05 by AIS2+ and P<0.01 by AIS3+).

Ankle joint/Foot: The fracture of the ankle joint/foot in AIS2+ increased (P<0.05).

THE CUMULATIVE FREQUENCY OF CAR MODEL YEARS in the dataset 1983-1986 and 1993-1996 is shown in Figure 3. The average model year of the cars was about 1978 in the dataset 1983-1986 and about 1986 in 1993-1996 . The average model year in the two time periods differs by about eight years (P<0.01). The proportion of the V-shape car and the Pontoon car was 11% and 89% respectively in 1983-1986,

Table 5 - Occurrence of injuries by different body regions

AIS	AIS2+			AIS3+		
	% with injury		Increase or	% with injury		Increase or
Region	83-86	93-96	decrease (%)	83-86	93-96	decrease (%)
Head	26.3%	26.2%	-1%	8.3%	6.1%	-27%
Face	4.0%	2.2%	-46%	0.3%	0.4%	62%
Neck	2.7%	0.9%	-68%	1.9%	0.9%	-54%
Shoulder/Arms	17.5%	11.4%	* -35%	7.5%	0.9%	** -88%
Chest/Thoracic spine	9.7%	5.2%	* -46%	5.4%	4.4%	-19%
Abdomen/Lumbar spine	5.1%	2.2%	* -57%	1.6%	1.3%	-19%
Pelvis/Hip joint	9.7%	7.0%	-28%	6.5%	3.9%	-39%
Thigh	5.1%	3.1%	-40%	4.8%	2.6%	-46%
Knee	14.5%	11.8%	-19%	8.6%	0.9%	** -90%
Lower leg	15.6%	11.4%	-27%	12.1%	3.1%	** -75%
Ankle joint/Foot	3.5%	7.9%	** 125%	1.6%	0.0%	* -100%
Legs	32.5%	28.8%	-11%	23.9%	6.1%	** -74%

Injury data 83-86:Head, Chest/Thoracic spine, Abdomen/Lumbar spine, Pelvis/Hip joint, Thigh, Knee and Lower leg injuries are classified by AIS85; Face, Neck, Arms and Ankle joint/Foot injuries are classified by AIS80
Injury data 93-96: All injuries are classified by AIS85

* P<0.05, ** P<0.01

Table 6 - Occurrence of specific injuries by different body regions

	AIS	AIS2+			AIS3+		
Region		% with injury		Increase or	% with injury		Increase or
	Injury type	83-86	93-96	decrease(%)	83-86	93-96	decrease(%)
Head	Concussion	18.0%	20.1%	12%	1.1%	0.4%	-59%
	Skull Fracture	6.7%	3.5%	-48%	5.1%	3.5%	-32%
	Intracranial injury	4.0%	6.6%	62%	3.8%	5.7%	51%
	Other injury	0.0%	0.4%		0.0%	0.0%	
Face	Fr nose/mandible/face	3.0%	2.2%	-26%	0.3%	0.0%	-100%
	Other injury	1.3%	0.4%	-68%	0.0%	0.0%	
Neck	Fr cerv sp with/ without cord inj	1.6%	0.9%	-46%	1.1%	0.9%	-19%
	Lux cerv sp without cord inj	0.5%	0.0%	-100%	0.3%	0.0%	-100%
	Cervical cord injury	0.5%	0.0%	-100%	0.5%	0.0%	-100%
Shoulder/ Arms	Fracture	15.6%	11.4%	** -27%	7.0%	0.4%	** -94%
	Luxation/distortion	2.2%	0.0%	-100%	1.1%	0.0%	-100%
	Other injury	0.5%	0.0%	-100%	0.0%	0.0%	
Chest/ Thoracic Spine	Fracture rib(s)/Sternum	4.3%	3.9%	-9%	3.0%	2.2%	-26%
	Pneumothorax, Hemothorax	3.0%	1.7%	-41%	3.0%	1.7%	-41%
	Cardiac inj, Lung injury	1.3%	2.6%	95%	1.3%	2.6%	95%
	Fracture thoracic spine	0.5%	0.9%	62%	0.3%	0.9%	225%
	Other injury	0.5%	1.3%	144%	0.5%	0.4%	-19%
Abdomen/ Lumbar spine	Organ injury	2.4%	1.7%	-28%	1.6%	0.9%	-46%
	Fracture lumbar spine	1.9%	0.4%	* -77%	0.0%	0.4%	
	Contusion/compression	1.3%	0.0%	-100%	0.0%	0.0%	
Pelvis/ Hip joint	Fracture pelvis	7.8%	3.5%	* -55%	4.3%	0.4%	** -90%
	Fr collum femur/trochanter	2.2%	3.5%	62%	2.2%	3.5%	62%
	Other injury	0.3%	0.0%	-100%	0.0%	0.0%	

* P<0.05, ** P<0.01

Table 6 - Continued

	AIS	AIS2+			AIS3+		
Region		% with injury		Increase or	% with injury		Increase or
	Type	83-86	93-96	decrease(%)	83-86	93-96	decrease(%)
Thigh	Fracture	4.8%	2.6%	-46%	4.8%	2.6%	-46%
	Other injury	0.3%	0.4%	62%	0.0%	0.0%	
Knee	Fracture	11.6%	7.0%	* -40%	8.6%	0.4%	** -95%
	Distortion (ligament injury)	4.0%	3.5%	-13%	0.0%	0.0%	
	Luxation	0.0%	0.9%		0.0%	0.9%	
	Deep laceration	0.0%	1.3%		0.0%	0.0%	
Lower leg	Fracture	15.6%	10.0%	* -36%	12.1%	3.1%	** -75%
	Other injury	0.3%	1.7%	550%	0.3%	0.0%	-100%
Ankle joint/ Foot	Fracture	3.5%	7.4%	* 112%	1.6%	0.0%	* -100%
	Other injury	0.0%	0.4%		0.0%	0.0%	

Injury data 83-86:Head, Chest/Thoracic spine, Abdomen/Lumbar spine, Pelvis/Hip joint, Thigh, Knee and Lower leg injuries are classified by AIS85; Face, Neck, Arms and Ankle joint/Foot injuries are classified by AIS80

Injury data 93-96: All injuries are classified by AIS85

Fr--Fracture, Cont--Contusion, Compr--Compression, Lac--Laceration, Lx--Luxation, Inj--Injury

Cerv-Cervical, Thor-Thoracic, Lumb-Lumbar, Sp-Spine, Org-Organ, J-Joint

* P<0.05, ** P<0.01

and 28% and 72% respectively in 1993-1996. The proportion of the V-shape car increased (P<0.01).

THE CUMULATIVE FREQUENCY OF THE TRAVEL SPEED of the cars in the two time periods is shown in Figure 4. The travel speed of the 50 percentile of cars was about 36 km/h in 1983-1986 and about 31 km/h in 1993-1996. The travel speed of the 50 percentile decreased by about 5 km/h. This result is in good agreement with the trend that the travel speed in cities in Sweden has decreased in recent years [8].

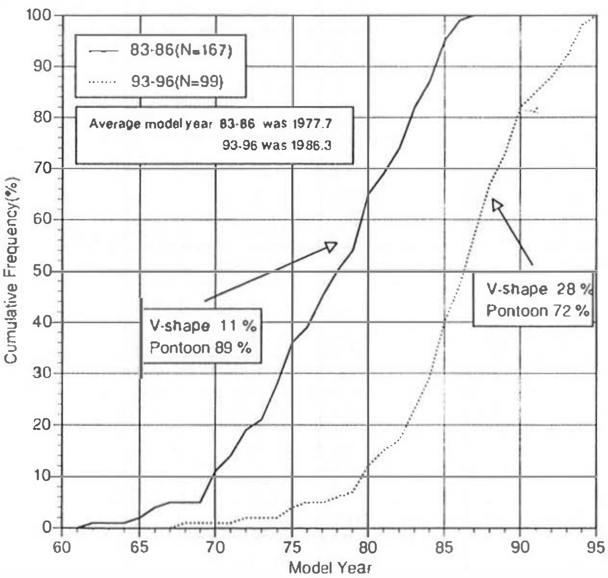

Fig .3 - Cumulative frequency of car model years in the data 1983-1986 and 1993-1996

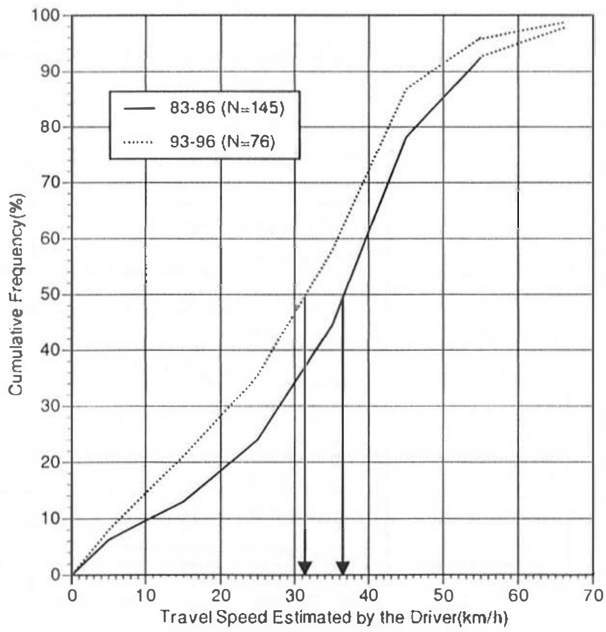

Fig. 4 - Cumulative frequency of the travel speed

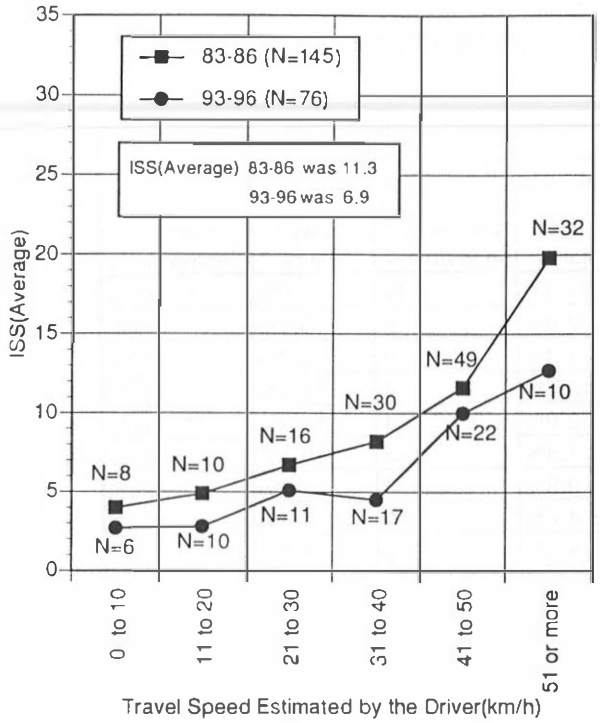

Fig. 5 - ISS (average) by the travel speed

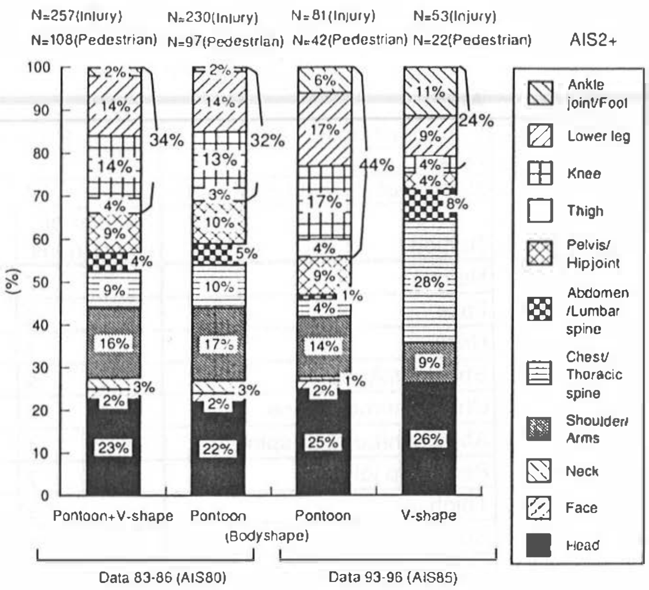

Fig. 6 - Comparison of relative frequency of injuries in different body regions by AIS 2+ between V-shape and Pontoon car

The impact speed seems to have decreased during the two time periods because the travel speed has good correlation to the impact speed [7].

THE ISS BY THE TRAVEL SPEED of the cars in the two time periods is shown in Figure 5. The average ISS in 1993-1996 was smaller than the ISS in 1983-1986 in each travel speed group. There appears to be a factor other than impact speed as the reason why ISS has decreased in these ten years.

THE RELATIVE FREQUENCY OF NON-MINOR (AIS2+) INJURIES BY BODY REGIONS AND CAR BODY SHAPE is shown in Figure 6. The relative frequency of chest/thoracic spine injury was higher for the V-shape car than for the Pontoon car (P<0.01).

THE OCCURRENCE OF NON-MINOR (AIS2+) INJURIES BY BODY REGIONS AND CAR BODY SHAPE is shown in Table 7. The occurrence of head, chest/thoracic spine and ankle joint/foot injuries was higher for the V-shape car than for the Pontoon car.

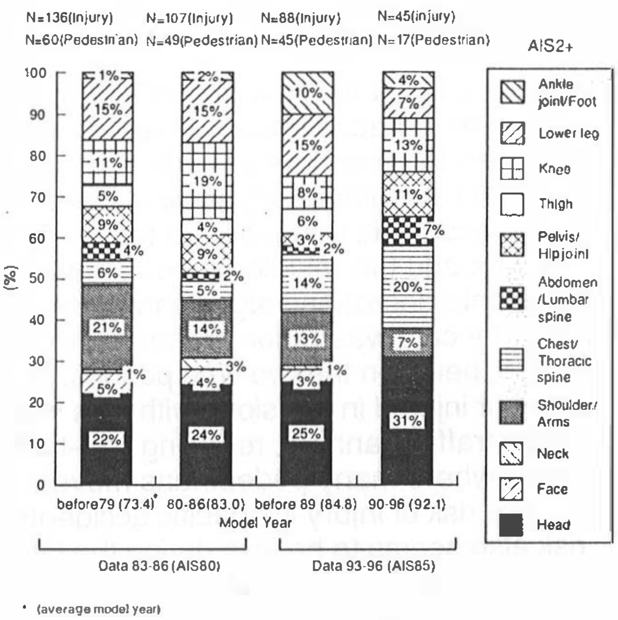

Fig. 7 - Relative frequency of injuries in different body regions by model year by AIS2+

THE RELATIVE FREQUENCY OF NON-MINOR (AIS2+) INJURIES BY MODEL YEAR of the cars in the two time periods is shown in Figure 7. The relative frequency of head and chest/thoracic spine injuries was higher for the car of the newer model year.

Table 7 - Occurrence of specific injuries by different body regions and car body shape

AIS2+

Car Body Shape	Pontoon		V-shape		
Data	93-96				
Number of Pedestrian (All AIS)	71		28		
Region	Number of pedestrians	% with injury	Number of pedestrians	% with injury	Increase or decrease(%)
Head	15	21.1%	12	42.9%	* 103%
Face	2	2.8%	0	0.0%	-100%
Neck	1	1.4%	0	0.0%	-100%
Shoulder/Arms	9	12.7%	4	14.3%	13%
Chest/Thoracic spine	2	2.8%	4	14.3%	** 407%
Abdomen/Lumbar spine	1	1.4%	3	10.7%	* 661%
Pelvis/Hip joint	7	9.9%	2	7.1%	-28%
Thigh	3	4.2%	0	0.0%	-100%
Knee	11	15.5%	2	7.1%	-54%
Lower leg	12	16.9%	4	14.3%	-15%
Ankle joint/Foot	5	7.0%	5	17.9%	* 154%
Legs	26	36.6%	9	32.1%	-12%

Injury data 83-86:Head, Chest/Thoracic spine, Abdomen/Lumbar spine, Pelvis/Hip joint, Thigh, Knee and Lower leg injuries are classified by AIS85; Face, Neck, Arms and Ankle joint/Foot injuries are classified by AIS80

Injury data 93-96: All injuries are classified by AIS85

* $P<0.05$, ** $P<0.01$

DISCUSSION

It is difficult to judge the risk of an accident without exposition data. However, the risk of traffic accidents in Gothenburg seems to have reduced during the ten years between the two time periods in this study. Data from The Traffic & Public Transport Authority in Gothenburg show a steady decreasing trend of all types of fatal and severe traffic accidents in relation to traffic intensity since 1970 (2). Between the middle of the eighties and the middle of the nineties, the number of fatal and severe car-pedestrian accidents decreased significantly. According to the police, the number of pedestrians killed by cars was reduced from 23 to 10, and the number of severely injured from 242 to 173, between the two time periods. According to this study, the number of pedestrians killed or injured in collisions with cars was reduced by 38%. The main reason is probably better traffic planning, reducing car -traffic intensity and/or preventing high velocities in areas where many pedestrians move.

The risk of injury in specific accidents can be estimated somewhat more easily. This risk also seems to be less during the later period. As shown in Table 4, the average ISS was reduced by 36% in all age groups, and especially for children (49%) and the elderly (39%). The main reason seems to be the reduced impact speed. The travel speed of the 50 percentile has decreased by 5 km/h in ten years (Figure 4) and because the travel speed has good correlation to the impact speed (7), the impact speed seems to have decreased in ten years. The impact speed is a critical parameter for the risk of injury. It is also important to remember that the relationship between the risk of injury and the impact speed is not linear. A reduction from 50 to 40 km/h impact speed, for instance, will reduce the risk of fatal injuries in pedestrians by about 60% (9). Therefore, even if the average impact speed has decreased by around 5 km/h, which seems to be little, a drastic decrease of ISS can occur.

Our data also indicate that the relative frequency and the occurrence of some injuries have changed significantly, especially the relative frequency of severe (AIS3+) injuries as shown in Figure 1. The relative frequency of head and chest injuries increased, and that of knee and lower leg injuries decreased. However the occurrence of severe head and chest injuries did not increase, and the occurrence of knee and lower leg injuries decreased (Table 5) . Passenger cars/taxies and the traffic environment in Gothenburg became much safer when the leg region is considered.

The occurrence of severe (AIS3+) knee fracture decreased by 95% between the two time periods (Table 6). All these knee injuries are fracture of the tibial condyle or the femoral condyle. One reason is the reduced impact speed, and another reason seems to be associated with the increase of plastic bumper systems in recent years. Note that the occurrence of knee ligament injury (AIS2) did not change between two time periods. This seems to be logical, because such injuries do not seems to be associated with the impact speed [10]. The occurrence of ankle joint/foot injury increased, and this seems to be associated with the geometry of the bumper system including the spoiler below the bumper [10].

The occurrence of severe (AIS3+) pelvis fracture decreased 90% between the two time periods (Table 6). This is important finding because pelvis fractures may be life-threatening and sometimes very difficult to treat. One reason of this decrease is the reduced impact speed, another reason seems to be the change of the body shape.

The shape of the car is important when the frequency of injury is considered. The relative frequency and the occurrence of some injuries were quite different between the V-shape and the Pontoon car. The relative frequency of head injury decreased and that of chest injury increased in ten years for children (Figure 2). The relative frequency of fracture of the collum femur/trochanter became larger than that of fracture of the pelvis by AIS 3+ in ten years (Table 6). This seems to be the result of an increase in V-shape cars in the later period. Generally the V-shape car has a lower bonnet edge than the Pontoon car, therefore the second contact point of the pedestrian hit by the car seems to be lowered. Also, the relative frequency of chest injury was higher for the V-shape car than the Pontoon car (Figure 6), and the occurrence of head and chest injuries was higher for the V-shape car than for the Pontoon car (Table 7) in 1993-1996. The same trend can be seen in Figure 7, which shows that the relative frequency of head and chest injuries was higher for the car of the newer model year. This result seems to be logical, as many new cars have a V-shape style. Although the proportion of V-shape cars has increased in ten years, the injury severity has decreased drastically. This seems to be the result of reduced impact speed. The impact speed is the most important factor when injury severity is considered.

The data in this study are quite limited concerning the number of cases for which the travel speed and the car design were estimated. In addition, we did not re-code all the AIS and ISS grades according to the differences in AIS80 and AIS85. This may make the results difficult to interpret. However, the results from this limited data indicate that the shape of the car has changed significantly and that some factors of the improved situation may be due to the car design. This seems especially valid for knee and lower leg injuries.

CONCLUSIONS

Proper planning of traffic safety investments is probably the most important tool by which the number of accidents and the severity of injuries can be reduced. This seems to have been carried out quite successfully in Gothenburg. However, there is still much to be done to reach the Swedish national goal, called the Zero Vision, which means no killed or severely injured road users. Even if this goal appears unrealistic in the short term, there is much need for such thinking.

Most of the improved situation for pedestrians in Gothenburg probably depends on better traffic planning. This is true for all age groups, but especially for children and the elderly. However, changes in car design seem to have influenced the distribution and the severity of the injuries. The risk of head and chest injuries was higher for the V-shape car than for the Pontoon shape car.

In some respects, modern cars seem to be safer than older cars. The risk of serious knee and lower leg injuries has been reduced. However, serious head and chest injuries are still common and they constitute more than half of the severe injuries in car-pedestrian accidents.

Impact speed is the most important factor when pedestrian injury severity is considered. Even a minor decrease of the impact speed will reduce the injury severity significantly.

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