Analysis of pedestrian injuries in pedestrian-car collisions with focus on age and gender

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I. INTRODUCTION

Pedestrians represent the majority of fatally injured vulnerable road users, accounting for about 23% of all fatally injured road users worldwide [1]. A detailed analysis of their injuries is needed to understand which ones are the most common, and to design measures to prevent these injuries.

While other studies have mainly focused on the relevance of various body regions using the AIS (Abbreviated Injury Scale) [2-4], the current study was carried out to investigate injuries in more detail. It was aimed to answer the following questions: Which injuries are the most important for the evaluation of pedestrian safety measures? And are there significant differences in the injuries sustained by pedestrians affected by their gender?

II. METHODS

Data from STRADA (Swedish Traffic Accident Data Acquisition) for the years 2016–2018 were used to analyse pedestrian-to-passenger car collisions. STRADA is a Swedish database with national coverage that includes information on road traffic accidents that is collected from emergency care hospitals and police reports [5]. Only information about accidents that was found in both police reports and hospital records was included in the present study. This information was available for 1,311 injured persons involved in 1,272 pedestrian-to-passenger car collisions; these persons sustained 3,198 injuries to which 442 different AIS codes were assigned.

To identify the most frequent pedestrian injuries, the full AIS 2005 codes were evaluated according to the AIS Codebook [6]. Injuries that affected an entire body area (e.g., affecting the skin and subcutaneous tissue, such as abrasions or hematomas) were not included in the current study. To investigate whether the factor of age influenced the type of injury sustained, the dataset was split into two age groups: Injuries sustained by pedestrians younger than 60 years old (YO) and by those equal or more than 60 YO. Furthermore, the odds-ratio (OR) [7] and the *p*-value from the chi-squared test [8] were calculated to determine whether females and males sustained significantly different injuries. The AIS codes were grouped by their first four digits for the analysis of significant differences between males and females due to the small sample sizes for individual AIS injury codes. It is possible to identify the injured body region and the atomic structure using the four-digit AIS code (e.g., organs, skeletal structures). Due to small sample sizes, injuries greater than AIS3 were not analysed in detail.

III. INITIAL FINDINGS

The three most frequent injuries observed in pedestrian-to-passenger car collisions according to the analysis of injuries categorized by the full AIS code are summarized in Tables I, with their rankings shown in the first column. Column two in each table shows the three most frequent AIS codes without taking the injury severity into consideration. Columns four and six represent the three most common AIS codes when taking the injury severity into consideration. Columns three, five and seven give the percentage of each injury relative to the total number of injuries (overall or for the respective injury severity).

TABLES I

THREE MOST FREQUENT AIS INJURIES FOR PEDESTRIANS BY AGE AND INJURY SEVERITY

Pedestrians < 60 YO							Pedestrians ≥ 60 YO						
Rank	AIS	% of AIS injuries (*n* = 2165)	AIS2	% of AIS2 injuries (*n* = 492)	AIS3	% of AIS3 injuries (*n* = 117)	Rank	AIS	% of AIS injuries (*n* = 1033)	AIS2	% of AIS2 injuries (*n* = 355)	AIS3	% of AIS3 injuries (*n* = 70)
1	161001.1	1.8%	650620.2	4.7%	450203.3	8.5%	**1**	161001.1	2.4%	854471.2	3.9%	450203.3	18.6%
2	640278.1	1.3%	854471.2	4.7%	150202.3	5.1%	**2**	854471.2	1.4%	858153.2	3.1%	853151.3	10.0%
3	854471.2	1.1%	**854251.2**	3.0%	854001.3	5.1%	**3**	450203.3	1.3%	856151.2	3.1%	853161.3	10.0%

The analysis showed that pedestrians < 60 YO sustained mild cerebral concussions without loss of consciousness as the most frequent injury (161001.1), followed by minor cervical spine injuries of the nerve root (640278.1) and then a moderate fibula fracture (854471.2). The three most frequent moderate injuries for this age group (AIS2) were lumbar spine fractures of the transverse process (650620.2), fibula fractures (854471.2) and simple fractures of the tibia shaft (854251.2). Among the serious injuries for this age group (AIS3), the rib cage fracture involving three or more ribs (450203.3) was the most frequent, followed by skull base fractures (150202.3) and open tibia fractures (854001.3).

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For elderly pedestrians some differences were observed: The most frequent injury sustained by this age group was again a mild cerebral concussion without loss of consciousness (161001.1) followed by a moderate fibula fracture (854471.2) and a serious rib cage fracture that involved three or more ribs (450203.3), without taking the injury severity into account. If the injury severity were taken into account, the most frequent moderate injuries sustained by this age group were fibula fractures (854471.2) followed by metatarsal fractures (858153.2) and pelvic ring fractures (856151.2). Among the serious injuries for this age group, a rib cage fracture that involved three or more ribs (450203.3) was again most common followed by femur fractures (853151.3, 853161.3).

Significant differences between males and females regarding their injuries were observed, with results listed in Tables II. This tables are split by age and by gender (OR greater than 1 = females and OR less than 1 = males). Females < 60 YO had higher odds of sustaining ankle joint injuries (8771**) and lumbar spine disc injuries (6506**) than males. Younger males had higher odds of sustaining thoracic injuries (4422**, 4414**), tibia shaft fractures (8542**), cerebellum injuries (1404**) and humerus shaft fractures (7512**) than females. Elderly females had higher odds of suffering distal tibia fractures (8543**), humerus fractures (7511**) and distal radius fractures (7523**) than elderly males. Elderly males had higher odds of suffering disc injuries of the thoracic spine (6504**) and the cervical spine (6502**) than elderly females.

TABLES II

GROUPED AIS INJURY CODES WITH A SIGNIFICANT DIFFERENCE IN GENDER WITHOUT TAKING INJURY FREQUENCY INTO CONSIDERATION

Pedestrians < 60 YO									
Higher odds for females (f)					Higher odds for males (m)				
AIS Group	% of injuries f (*n* = 1185)	% of injuries m (*n* = 980)	OR	*p*-Value	AIS Group	% of injuries f (*n* = 1185)	% of injuries m (*n* = 980)	OR	*p*-Value
8771**	1.5%	0.6%	2.5	0.046	4422**	0.5%	1.4%	0.4	0.026
6506**	2.2%	1.0%	2.2	0.035	4414**	0.8%	2.1%	0.3	0.006
					8542**	0.8%	2.9%	0.3	0.006
					1404**	0.3%	1.3%	0.2	0.004
					7512**	0.1%	1.0%	0.1	0.003

Pedestrians ≥ 60 YO									
Higher odds for females (f)					Higher odds for males (m)				
AIS Group	% of injuries f (*n* = 590)	% of injuries m (*n* = 443)	OR	*p*-Value	AIS Group	% of injuries f (*n* = 590)	% of injuries m (*n* =443)	OR	*p*-Value
8543**	1.7%	0.2%	7.6	0.024	6504**	0.5%	2.0%	0.3	0.023
7511**	1.9%	0.5%	4.2	0.045	6502**	0.5%	2.3%	0.2	0.013
7523**	3.2%	0.9%	3.7	0.013					

IV. DISCUSSION

In this study, the global AIS body regions were also analysed to compare the results with those that have been obtained in other studies. The three most commonly injured AIS2+ body regions were identified as the lower extremities (42%), the grouped body region head/face/neck (17%) and the upper extremities (15%). These results correspond with the findings of [2-4]. When considering AIS3+ injuries, the upper extremities are replaced by the thorax, which is again in accordance with results from other studies, such as [3].

The analysis of the most frequent injuries (Tables I) showed that bone fractures were the most frequent injuries received by pedestrians regardless of their age or sex. This highlights that future research on Human Body Model developments should place a focus on bone modelling and the prediction of fractures. Significant differences between the injuries sustained by males and females were observed, and these differences were even more pronounced when younger and elderly pedestrians were compared. The injury severity ratings assigned to males and females were significantly different: Males < 60 YO had significantly higher odds of sustaining AIS3 injuries than females (OR = 0.4 p = 0.00004). The influence of exposure could not be assessed from the current study results, as information on impact severity (i.e. collision speed) is not available in the STRADA dataset. This aspect should be analysed in a future study using databases with more in-depth information and by carrying out simulation studies with Human Body Models.

The findings of this study highlight the need for an assessment of safety measures that takes both, the gender and age of people, involved in pedestrian-to-passenger car collisions into consideration. While it is not possible to examine this aspect with the current impactors, this can be addressed by means of virtual testing.

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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