Upper-body injuries in bicyclists caused by the car front

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I. INTRODUCTION

Former studies [1-6] showed that the bonnet is the most frequent vehicle structure causing upper-body injuries in pedestrians hit by the car front. When investigating the mitigation and prevention of injuries in vulnerable road users (VRUs) hit by cars, vehicle testing with pedestrian surrogates is performed at collision speeds up to 40 km/h, addressing head, pelvis and lower extremity injuries. However, the need to protect pedestrians and bicyclists from upper-body injuries in inevitable impacts remains to be discussed. In this study, focus is set on bicyclists with upper-body injuries caused by the car front. It is analysed if the bonnet can be confirmed to be of major importance when attempting to mitigate or prevent upper-body injuries through vehicle design. For this short communication, as a first step, in particular, vehicle type Sedan is regarded.

II. METHODS

Reconstructed bicyclist accident cases from the German In-Depth Accident Study (GIDAS, database version as of July 2021) were selected, applying the following inclusion criteria: only two participants (one vehicle, one bicyclist); vehicle category M1 or N1; accident year >2005; manufacturing year of motor vehicle >1996 (5,081 bicyclists). Further, the bicyclist needed to show an upper-body injury of AIS2+ (coded by Abbreviated injury Scale AIS© 2005 update 2008) [7] (reducing sample to 291) caused by any front structure (GIDAS variable VTEIL1 520-572) (leading to 100 cases). In this study, the upper body was defined based on AIS codes, including: AIS region 4 (thorax), thoracic spine, liver, spleen, kidneys, clavicle, scapula, proximal humerus, acromioclavicular-, sternoclavicular-, and glenohumeral-joint.

One case was excluded as the upper-body injury was caused by overrun by the front wheel. The sample was further reduced to cases where the relative speed was 50 km/h at maximum. In comparison to pedestrians, the intrinsic speed of the bicyclist contributes meaningfully to the interaction, therefore the limit was not applied to the collision speed of the vehicle. In total, 77 bicyclists (48 male, 29 female) remained in the study sample. A descriptive analysis was performed to show in which circumstances the bicyclists sustained an AIS2+ upper-body injury. Further, for the vehicle type Sedan, these injuries were cross-tabulated with the injury-causing vehicle structures and impact locations contained in the GIDAS data and are presented for both sexes.

III. INITIAL FINDINGS

Both male and female bicyclists had a median age of 42 years (range in males: 13 yo to 75 yo, in females: 9 yo to 79 yo). 50% (n=24) of the male and 41% (n=12) of the female bicyclists were hit by a Sedan; 42% of the males (n=20) and 52% of the females (n=15) were hit by an MPV. An SUV was the opponent for four men, a transporter for two women. 40% of the men and 70% of the women were on a touring bicycle and 17% of the men and 24% of the women on a bicycle without further specification. 31% of the men were riding a mountain bike and 10% a racing bicycle. One man was riding an electric bike. The female bicyclists were hit from the front (10 o'clock to 2 o'clock, most frequently from oblique) in 86% of cases, the males in 69% of cases. Four men were hit from the back (6 o'clock). The median relative speeds (minimum; maximum in brackets) were 30 km/h (12; 50) for men and 31 km/h (12; 45) for women. The median collision speeds of the vehicles were 28.5 km/h (7; 74) for men and 27 km/h (0; 55) for women. The median speeds of the bicyclists at the impacts were 20 km/h (7; 35) for men and 19 km/h (11; 28) for women. Two men and two women wore protective jackets (4% and 7%, respectively). The Injury Severity Score ISS was below 16 for 92% of the male and 83% of the female bicyclists, with highest ISS values of 38 and 29, respectively. The maximum AIS in the upper-body region (MAIS(UB)) was 2 for 75% and 72%

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(male/female), MAIS(UB)3 for 23% and 21%, MAIS(UB)4 for two women and MAIS(UB)5 for one man. The 77 bicyclists suffered from 105 AIS2+ upper-body injuries (both sexes, all vehicle types). With 46%, the bonnet was the most frequent injury causing vehicle part of these injuries, followed by the windscreen in 33%.

Regarding only vehicle type Sedan, 36 bicyclists suffered from 54 AIS2+ upper-body injuries (both sexes). With 48% (26 of 54 injuries), the bonnet was the most frequent injury causing vehicle part of these injuries, followed by the windscreen in 35% (19 injuries). The bonnet impact caused, in particular, fractures of the clavicle (n=8) of the rib cage (n=5), and kidney injuries (n=4). The windscreen impact caused, in particular, fractures of the clavicle (n=5) and of the rib cage (n=3). Table I shows these 54 injuries (AIS Code on 4-digit level) cross-tabulated with the injury-causing part, for both sexes. One man showed three upper-body injuries caused by two different structures (lung and rib cage by bonnet, clavicle by windscreen), all other bicyclists showed only one injury-causing structure for their upper-body injuries. In five of the 15 clavicle fractures a shaft fracture was documented, in four cases a distal fracture, in nine cases the fracture location was not specified.

TABLE I

INJURY-CAUSING PART/LOCATION OF IMPACT OF 54 AIS2+ UPPER-BODY INJURIES (4-DIGIT LEVEL WITH AIS SEVERITIES OCCURRING IN DATA) IN 36 BICYCLISTS WITH UPPER-BODY INJURIES CAUSED BY A SEDAN FRONT

SEDAN, 24 males, 12 females	**front wing from frontal**		**bonnet**		**windscreen wipers**		**windscreen**		**A-pillar**		**Sums per sex**		**Sum both sexes**
	m	f	m	f	m	f	m	f	m	f	m	f	
Lung (AIS2,3)			1	1			3				4	1	5
Thoracic injury, Haemothorax (AIS2)			1	1			1	1	2		4	2	6
Rib Cage (AIS2,3,4)			3	2			1	2	2		6	4	10
Sternum (AIS2)								1				1	1
Kidney (AIS2)			2	2							2	2	4
Spleen (AIS2,3)							1	1			1	1	2
TS Vertebra (AIS2,3)			1				1				2		2
Clavicle fracture (AIS2)	1		5	3			4	1	1		11	4	15
Scapula fracture (AIS2)	1			1	1			1	1		3	2	5
Proximal humerus fracture (AIS2)				2								2	2
Glenohumeral joint (AIS2)			1					1			1	1	2
Sums per sex	2	0	14	12	1	0	11	8	6	0	34	20	54
Sum both sexes	2		26		1		19		6		54		

IV. DISCUSSION

As seen in the previous study of pedestrians [6], the injury-causing structure of an opposing vehicle hitting a bicyclist is most frequently the bonnet, however the windscreen is seen more frequently than in pedestrian accidents. Proximal humerus fractures are found less frequently and, due to low case numbers, only in females. Clavicle fractures occurred more often, as has been reported before [8-10]. Higher body centre of gravity when sitting on a bicycle and higher speeds might lead to slightly different impact conditions of the upper body when hitting the car front. Most of the fractures are in line with a lateral, direct impact of the upper body. This mechanism can lead to clavicle fractures, yet an impact on the extended arm (as protection against fall) could also be causative. The thoracic vertebra fractures and solid organ injuries will be analysed in connection with the individual injury pattern to see if other mechanisms also apply. Prior to final recommendations for an improvement of the vehicle front, especially bonnet and windscreen, to protect bicyclists from thoracic injuries, further in-depth biomechanical considerations are needed.

V. REFERENCES

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