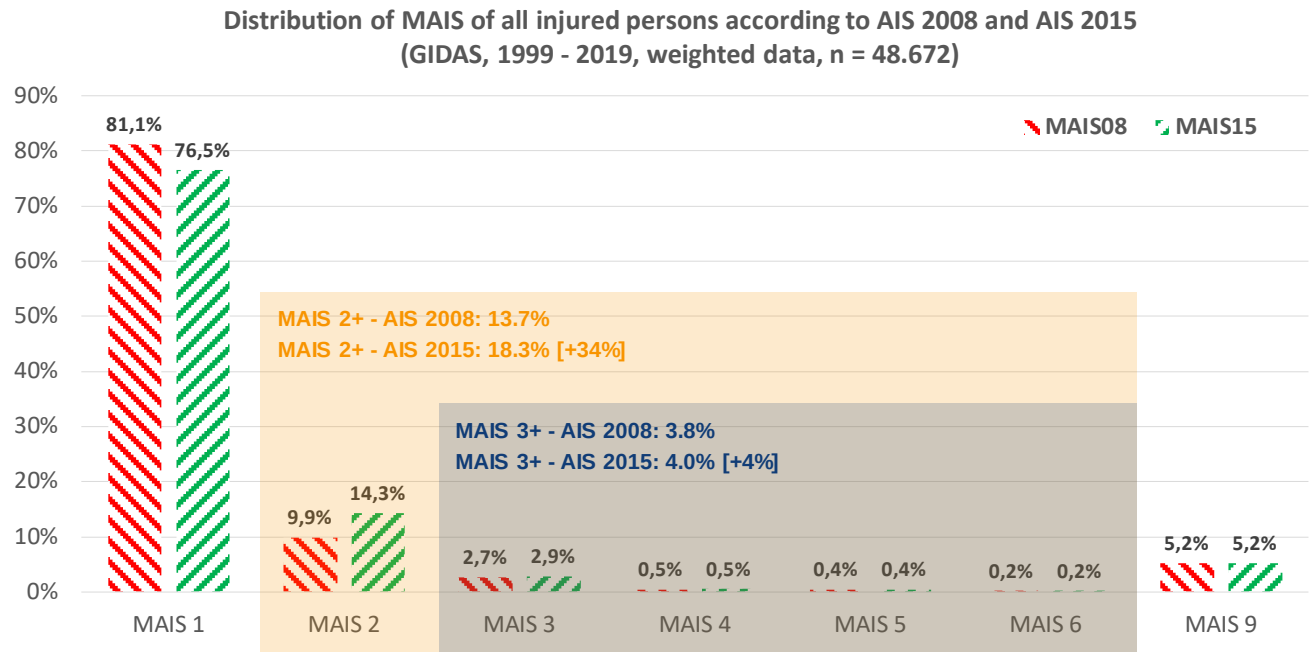

Fig. 7. Distribution of MAIS of all injured persons in GIDAS (AIS 2008 vs. AIS 2015).

The most important findings from this figure are:

- There is an increase of both the share of MAIS 2+ and MAIS 3+ injured persons when using the AIS 2015.
- The proportion of MAIS 2+ injured persons strongly increased by 33.9% (13.66% → 18.29%).
- The proportion of MAIS 3+ injured persons moderately increased by 4.2% (3.80% → 4.96%).
- There are less MAIS 1 injured persons, which are usually referred to as *slightly injured*.
- The shares of MAIS 4, MAIS 5, and MAIS 6 (and MAIS 9) remain rather constant.

The observed changes are very important as many stakeholders, i.e., legislators, manufacturers and suppliers, authorities, consumer protection organisations, etc., in the field of road safety focus on MAIS 2+ and/or MAIS 3+ injured persons as protective goals for road safety innovations. On the European level, for example, the classification into *seriously injured road casualties* should be done with the criteria *MAIS 3+ injured* [4]. As this information is not investigated by the German police and thus, not available in the official road accident statistics of Germany, the information is gained by extrapolation of GIDAS data and thus, will be directly affected by the used AIS revision.

For a better understanding of the consequences of the AIS 2015, the results of some analyses are provided here to get better insights into the MAIS shifts caused by the AIS2015 codebook for different types of road users. Figure 8 shows that the impact of the use of the AIS 2015 depends on the type of injured road user. The diagram shows that (injured) car occupants are less often MAIS 2+ injured than bicyclists and pedestrians. However, there is a strong increase in the portion of MAIS 2+ injured persons in each group. The proportion of MAIS 2+ injured car occupants (ECE classes M1 and N1) increases by 52% (from 9.1% to 13.8%). For bicyclists and pedestrians the increase is 30% and 27% respectively, which results in tremendous changes in reference to *seriously injured persons*. This is a strong indication that there are some single injuries that occur very often and that were shifted to higher AIS levels (namely, from AIS 1 to AIS 2) in the AIS revision 2015.

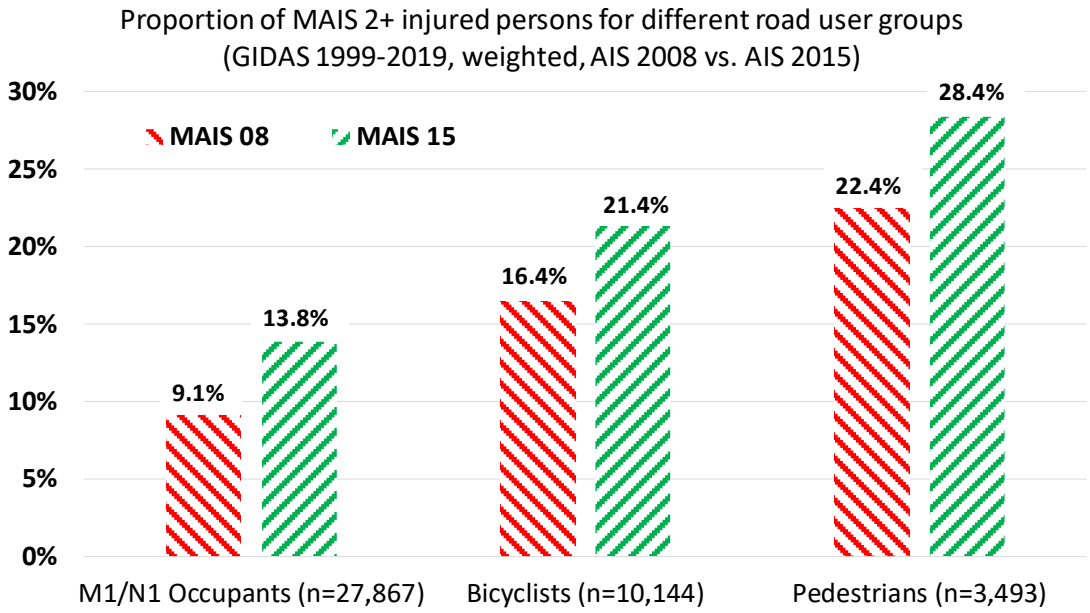

Fig. 8. Proportion of MAIS 2+ injured road users for AIS 2008 and AIS 2015 (GIDAS 1999-2019, weighted data).

The analysis for MAIS 3+ injured casualties (Figure 9) shows that there are only slight changes between MAIS 08 and MAIS 15. The proportion of MAIS 3+ injured persons slightly increases in all road user groups. For bicyclists, the (relative) increase is the highest with 6%, followed by M1/N1 passengers (+ 4%) and pedestrians (+ 3%).

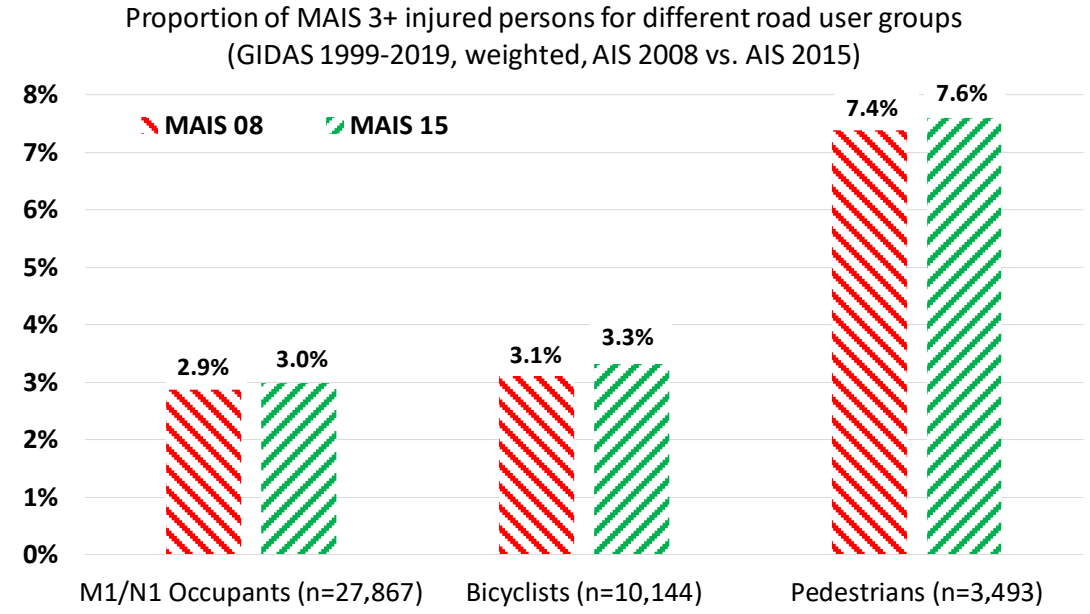

Fig. 9. Proportion of MAIS 3+ injured road users for AIS 2008 and AIS 2015 (GIDAS 1999-2019, weighted data).

In the next step, the focus was on affected body regions. Therefore, the example of severely injured (MAIS 3+) cyclists was used to illustrate potential changes more in detail. Figures 10 and 11 provide the number of MAIS 3+ injured bicyclists, their total number of injuries and the number of AIS3+ injuries. The following conclusions can be derived from the figure:

- The number of MAIS 3+ injured bicyclists increased by 6.0% from 318 (AIS 2008) to 337 (AIS 2015).
- A substantial increase in AIS3+ injuries were observed in the body region *upper extremities* when applying the AIS revision 2015.
- The frequency of AIS 3+ injured body regions seemed to decrease slightly in the majority of body regions, which is mainly a consequence of more MAIS 3+ injured bicyclists. However, the absolute number of AIS3+ injuries was not changing in the most body regions.

MAIS 3+ injured bicyclists (n = 318)			
AIS 2008			
AIS body region	Number: region injured (n_{Inj})	Number: region AIS3+ injured (n_{AIS3+})	Ratio (n_{Inj}/n_{AIS3+})
Head	201	142	71%
Face	119	14	12%
Neck	11	3	27%
Thorax	123	90	73%
Abdomen	38	13	34%
Spine	61	21	34%
Upper extr.	173	6	3%
Lower extr.	195	104	53%
External/other	7	0	0%

Fig. 10. Injured body regions of MAIS 3+ bicyclists according to AIS 2008.

MAIS 3+ injured bicyclists (n = 337)			
AIS 2015			
Body Region	Number: region injured (n_{Inj})	Number: region AIS3+ injured (n_{AIS3+})	Ratio (n_{Inj}/n_{AIS3+})
Head	204	141	69%
Face	1227	14	12%
Neck	11	3	26%
Thorax	125	89	71%
Abdomen	39	13	32%
Spine	61	21	34%
Upper extr.	190	27	14%
Lower extr.	202	103	51%
External/other	8	0	0%

Fig. 11. Injured body regions of MAIS 3+ bicyclists according to AIS 2015.

The reason for this substantial change in the proportion of AIS3+ injuries on the upper extremities was the severity change of around 15 injuries in the AIS revision 2015 (from AIS2 to AIS 3), most of them open radius, ulna, or humerus fractures. As these injuries occur quite often to MAIS3+ injured bicyclists, the ratio changes strongly.

It can be clearly seen that single injuries may have a remarkable effect on the overall injury severity and even influence the MAIS distributions in larger datasets. Therefore, the last analysis in this paper deals with the substantial changes between MAIS 1 (*slightly injured*) and MAIS 2+ (*seriously injured*) persons (see Figure 7) for different road user groups.

The goal was to identify the relevant single injuries that led to the significant increase in the share of MAIS 2+ injured persons for car occupants (+52%), bicyclists (+ 30%) and pedestrians (+ 27%). Therefore, the most frequent injuries for each road user group were extracted from the database and severity changes were identified. Then, the relevance of these injuries for the overall injury severity was analysed. The results are the following:

Passenger car occupants

Relevant injuries include:

- 161001.2 (mild concussion, no loss of consciousness), 2.2% of all injuries
- 161000.2 (cerebral concussion NFS); 0.8% of all injuries

Although the frequencies of these two injuries were not extremely high, the relevance of these injuries in terms of MAIS is high. Out of all 28,285 injured car occupants in GIDAS, 1,761 (6.2%) suffered one of these injuries. The important fact is that for 1,371 persons (4.8% of all injured car occupants) the concussion was the only AIS2 injury, defining the person as MAIS 2 injured.

Bicyclists

Relevant injuries include:

- 161001.2 (mild concussion, no loss of consciousness), 1.8% of all injuries
- 161000.2 (cerebral concussion NFS); 0.5% of all injuries

Out of all 10,316 injured bicyclists in GIDAS, 716 (6.9%) suffered one of these two injuries. Again, for the majority of them (520 persons; 5.0% of all injured bicyclists) the concussion was the only AIS2 injury, resulting in the MAIS 2 according to the AIS 2015.

Pedestrians

Relevant injuries include:

- 161001.2 (mild concussion, no loss of consciousness), 2.3% of all injuries
- 161000.2 (cerebral concussion NFS); 0.7% of all injuries

Out of all 3,522 injured pedestrians, 322 (9.1%) suffered one of these two injuries. Two-hundred and thirteen (6.1% of all injured pedestrians) suffered a concussion as the only AIS2 injury, resulting in an MAIS 2 according to the AIS 2015.

The comparison of the numbers in Figure 8 describing shares of people only suffering a concussion as the most severe injury shows that the increase in the MAIS 2+ numbers solely based on these two injury codes. As they are very prominent in accidents, they completely influence the distribution of overall injury severity.

IV. DISCUSSION

This paper deals with the implementation of the recently published AIS revision 2015 in an accident database (GIDAS) and the resulting effects. Although the GIDAS database also provides AIS 1998 codes, only the AIS revisions 2008 and 2015 are compared in this paper. The revisions of the Abbreviated Injury Scale represent the current status in emergency medicine, trauma surgery, and polytrauma management. For accident research and road safety initiatives, it is necessary to incorporate these developments into accident databases. The changes of the AIS 2015 coding range from re-grouping, severity changes, splitting or aggregating injuries to new codes.

The main goal of this work was to analyze the influence of these changes in terms of injury severity and to assess the resulting outcome of casualties involved in accidents. Therefore, GIDAS data was used as this dataset contains information about single injuries and provides AIS codes.

Basically, a remarkable number of injury codes were reduced in terms of injury severity. However, the analysis of documented traffic accidents in GIDAS shows that the proportion of moderately injured (MAIS 2+) and severely injured (MAIS 3+) persons in traffic accidents increases when applying the new AIS 2015 to the GIDAS data. For example, the proportion of MAIS 2+ injured persons increased substantially for several types of road users. There was also an increase in the portion of MAIS 3+ injured persons whilst the magnitude is not that high as for MAIS 2+ injured casualties.

Further analyses showed that particular body regions are especially affected by the changes between AIS 2008 and AIS 2015. This, for example, includes the region *upper extremities* where the frequency of AIS 3+ injuries increased substantially (for bicyclists) as the severity of open radius, ulna, and humerus fractures was changed from AIS 2 to AIS 3.

The most important changes with a remarkable impact on accident databases are found in the body region *head*. Here, the severity of two single injuries (concussion injuries) has been changed from AIS 1 to AIS2. As between 6% (car occupants) and 9% (pedestrians) of all injured road users suffer these injuries, the effect on the overall injury severity (expressed by the MAIS) is tremendous.

The results of the paper demonstrate the importance of introducing and using appropriate injury scales and evaluation of codebook changes. For a focused and goal-oriented development of measures and systems for traffic and vehicle safety, current medical developments must also be taken into account. Otherwise, wrong priorities may be set.

Finally, the used dataset and applied weighting methods have some limitations. The complete GIDAS dataset was used for the study, containing accidents from 1999 to 2019. The data was then weighted towards the German road traffic accident statistics of the year 2018 to remove biases in the data that are typical for in-depth databases. The weighting of 20 accident years to one year in the national statistics may mask some effects and/or recent developments. However, annual weighting for each year is not appropriate because of the “small” number of cases per year (around 2,000) and the large number of weighting categories (63). In order to solve this problem, a limitation to a certain period of time (e.g. last decade) could be useful as far as the number of cases is still sufficient to achieve robust and/or statistically significant results.

V. CONCLUSIONS

For the evaluation, development, prioritization, and legislation of future safety measures, it is essential to also assess accident consequences according to the current state of medical care and rescue medicine. The application of the AIS Revision 2015 will lead to a better understanding of the severity of traffic accidents. The changes will lead to shifts in the ratio of minor, moderate and severe injuries.

The shifts show that the proportion of serious (AIS 3+) injuries will increase with the application of the AIS Revision 2015. Depending on the type of road user, this increase varies. The application of the scale means that safety developments can be better focused and prioritised in line with the occurrence of severe accidents and current medical knowledge. With the help of the presented findings, even more targeted safety measures can be derived, which can lead to a reduction in the number of MAIS 3+ injured casualties.

VI. ACKNOWLEDGEMENT

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