Pedestrian Leg Injury Distribution in German in-depth Accident Study for Leg Impactor Development

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I. INTRODUCTION

Lower extremity injuries account for 33% of pedestrian Abbreviated Injury Scale (AIS) 2+ injuries in passenger car-to-pedestrian collisions [1]. In order to reduce these injuries, subsystem leg impactors have been developed that aim to reproduce leg kinematics and estimate leg injuries when propelled against a vehicle front. In current legal requirements [2], leg impactor tests and injury thresholds for tibia bending moments and knee ligament elongations must be complied with to reduce leg injuries. However, no study was found in literature that investigated in detail the distribution of different types of leg injury in real-life collisions. In view of current efforts to develop a new leg impactor, the present study shows detailed leg injury distributions from passenger car-to-pedestrian collisions. Furthermore, this study aims to support future leg impactor development by investigating how many of the injuries occurring in real-life collisions are currently addressed.

II. METHODS

The unweighted German In-Depth Accident Study (GIDAS) database was queried for pedestrians who experienced a collision with one passenger car front (no other collision partner involved), did not lie on the ground at first impact, were not rolled over by the car, and the AIS2008 injury code in the database was not empty or unknown. Further limitations, regarding, e.g. injury severity or car model year, were not made. This yielded 1,730 pedestrians. Out of these, the number of pedestrians with at least one AIS2008 leg injury (excluding eight pedestrians with unknown injuries 800099.9, 800999.9, 840099.9, and 850099.9) was determined.

Subsequently, the numbers of pedestrians with one of the following leg injuries were collected: (1) at least one long bone fracture (LBF) but no knee ligament injury (KLI); (2) at least one KLI but no LBF; (3) at least one LBF and at least one KLI. LBFs were further split into femur, tibia and fibula fractures, whereas KLIs were split into medial & lateral collateral ligament (MCL/LCL) and anterior & posterior cruciate ligament (ACL/PCL) injuries. In addition, other leg injuries occurring in these cases were examined.

III. INITIAL FINDINGS

Three-quarters of the 1,730 pedestrians (n=1316 or 76.1%, Fig. 1) sustained at least one AIS1+ leg injury. In total, the 1,730 pedestrians sustained 7,248 injuries, of which 2,604 (35.9%) were AIS1+ leg injuries. A total of 347 (20.1% of 1,730) pedestrians sustained a LBF but no KLI, nine (0.5%) a KLI but no LBF, and 14 (0.8%) at least one LBF and at least one KLI (Fig. 1b). Pedestrians with LBFs sustained femur fractures in 62 (3.6%) cases, tibia fractures in 257 (14.9%) cases and fibula fractures in 149 (8.6%) cases (multiple injuries per case allowed, Fig. 1c). Pedestrians with KLI sustained ACL/PCL or MCL/LCL injuries in equal numbers (Fig. 1d).

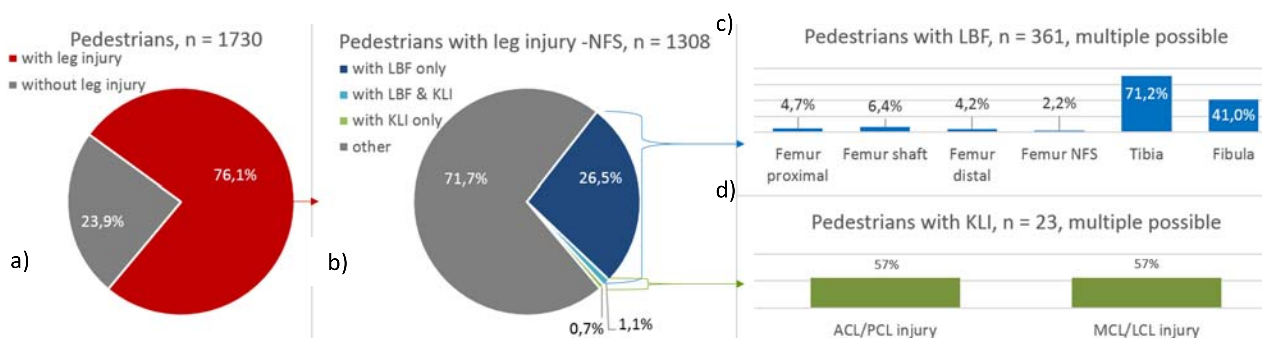

Fig. 1. Distribution of long bone fractures and knee ligament injuries among n=1,730 pedestrians.

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In addition, 19 pedestrians sustained other KLIs, such as dislocations, of which seven additionally sustained a LBF and one additionally sustained a LBF and KLI. Nine pedestrians sustained a patella fracture, and seven sustained a meniscus injury (multiple injuries possible). These 616 injuries (LBFs, KLIs, patella fractures, knee joint and meniscus injuries) were deemed directly or indirectly addressable by current leg impactors.

Furthermore, 1,988 lower extremity injuries occurred that were deemed non-addressable by current lower leg impactors, of which 134 were pelvis injuries which can, to some extent, be addressed with the upper leg impactor. Among the non-pelvic injuries, AIS1 soft tissue (skin, subcutaneous and muscle) injuries were dominant (94.2% of 1,854 injuries, Fig. 2a). Among the non-pelvic injuries that were not AIS1 soft tissue injuries, most were AIS1 and AIS2 foot and ankle injuries (Fig. 2b).

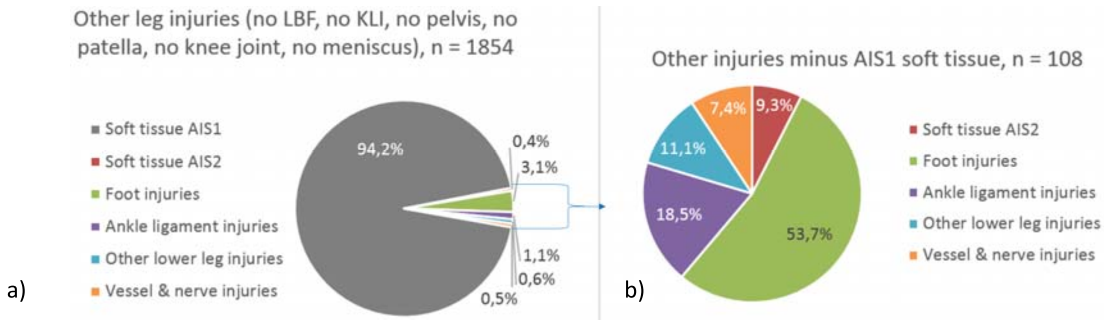

Fig. 2. Distribution of n=1,854 other lower leg injuries (excluding LBFs, KLIs, patella fractures, knee joint, meniscus injuries).

IV. DISCUSSION

Current lower leg impactors measure tibia bending and knee ligament elongations, although only 16.1% of all pedestrians in the present study sustained a tibia fracture or a knee ligament injury. Arguably, when reducing tibia fractures, a certain amount of fibula fractures will likely be prevented as well. Femur and patella fractures, knee joint and meniscus injuries could, in theory, be addressed with suitable updates to the leg impactors if human-like injury risk would be reproduced with such updates and corresponding injury thresholds. Pelvis injuries (134 of 7,247 injuries) can, to some extent, be addressed by the upper leg impactor, whereas addressing foot and ankle ligament injuries (78 of 7,247 injuries) would require major impactor remodelling.

Filters in this study were set conservatively, aiming at yielding the maximum number of injuries in car-to-pedestrian collisions. So, for example, older cars and injuries from secondary impact were included. However, this study only looked at one database from Germany; injury distributions in other regions could be different.

Among the already addressable injuries, in contrast to LBFs (361 out of 1,730 cases), the occurrence of KLIs was small (23 out of 1,730 cases). Previous studies in French databases have also found few KLIs, and the majority of leg injuries were also AIS1 [3-4]. Current KLI thresholds for leg impactors were previously derived through a combination of experiments, finite element simulations and transfer functions [5-7]. Thus, muscle contraction as an influence factor was possibly indirectly, but not directly, considered. Nevertheless, muscle contraction has been suspected of reducing the likelihood of KLIs while increasing the likelihood of LBFs [8].

In order to effectively prevent pedestrian leg injuries, the authors would like to encourage an open discussion on the injury focus of future leg impactor development. Future studies and development in this direction should investigate the biomechanics of leg injuries, their mechanisms and thresholds. Some of the factors influencing pedestrian leg injuries may include muscle contraction, ground force, pedestrian posture at the time of impact, knee height with respect to bumper height, pedestrian age and other individual differences, as well as vehicle differences, such as geometry and stiffness, vehicle speed and braking. Furthermore, the possibility of reducing all different types of pedestrian injury through collision avoidance or speed reduction by active systems should be thoroughly investigated in parallel.

V. REFERENCES

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