Adaptive Restraints: Suggested Parameters for Occupant Classification System.

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Abstract The research focuses on three main issues: Can a real population be fit into the set of standardized crash test dummies? What influence do the differences between dummies and real occupants have on the level of safety of the occupants? Which parameters should the occupant classification system measure to adapt the settings of passive safety devices to the individual needs? The answer was approached in three steps. The first step was analysis of two crash databases, taking into account anthropometry of the drivers and their injury level. The second step was development of a matrix of numerical simulations with use of crash test dummies, scaled in such a way as to address various height and weight of the occupants. Finally, the simulation results were compared to the trends in the crash databases.

Keywords Passive safety, adaptive restraints, crash test dummies

I. INTRODUCTION

A new challenge for passive restraint systems are adaptive restraints, which means devices adjustable to the characteristics and needs of an individual occupant. An occupant classification system ascribes the occupant to a certain group of airbag, pre-tensioner, force limiter, or seat position predefined settings based on measured parameters. The dimensions of crash test dummies used for certification tests are based on anthropometric data from the 1970s and earlier, but the population has significantly changed since that time[1]. Therefore, a need exists to adjust the dummies to the current population or to introduce new dummies [2]. 60% of all the fatalities in vehicle collisions occur in frontal crashes [3]. The head and chest are the body regions that receive the most serious injuries in frontal crashes; therefore, the focus here is on head-on collisions and head and chest trauma [4].

II. METHODS

The methodology consisted of three main steps. The first one was a statistical approach of examining trends in crash databases, focusing on assumed anthropometric parameters (height, weight, Body Mass Index). These parameters were chosen as relevant based on current literature. Plausibility of the results was verified with WHO (World Health Organisation) data. The second step was to perform numerical simulations, using dummies of different height and weight, seated on the driver's side in a mid-size car. For this purpose, MADYMO software was used. The numerical model of the car was equipped with belt pre-tensioners, belt force limiter and an air-bag. The crash pulse used was EuroNCAP ODB. The third step was to compare the statistical data with the results of the numerical simulations.

Real-World Statistical Data

The source for statistical investigation were crash databases: GIDAS (German In-Depth Accident Study) and NASS-CDS (National Automotive Sampling System – Crashworthiness Data System). For a comparison, current literature and WHO statistical data were used. For the anthropometry analysis, all the drivers from the databases were considered. For the injury risk comparison, only drivers involved in single-collision frontal crashes in passenger cars having a MAIS equal to 3 or higher were included. Injury risk for head and chest was taken into account for AIS 2+ injuries.

BMI was chosen as one of the parameters as it has been shown that effects of height and weight on injury risk are incorporated within BMI [4]. BMI itself is not a perfect predictor of injury risk; however, a trend of increase of MAIS 2+ chest injuries with increase of BMI was observed by Jakobsson et al. in Swedish crash dataset in both belted and unbelted occupants in frontal crashes [5]. BMI is combined with height in this study. Height ranges of 165cm, 180cm and 190cm were chosen in order to have a relatively even distribution within the height-weight cells.

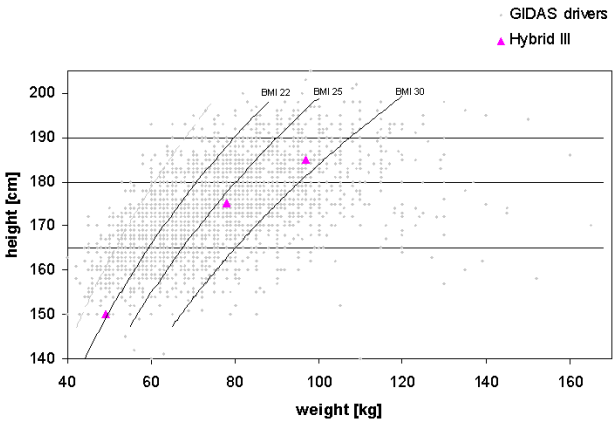

Fig. 1. Weight-height diagram, showing distribution of the drivers from GIDAS database (little dots) and standard crash test dummies (triangles). Horizontal lines separate different ranges of height, skew curves mark ranges of BMI 22, 25 and 30 (left to right).

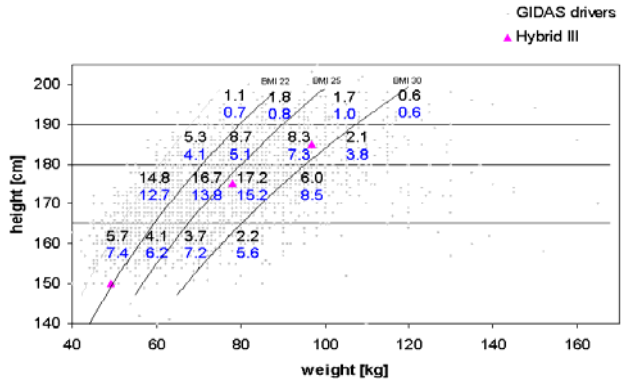

Fig. 2. Weight-height diagram with distribution of drivers from GIDAS (dark numbers) and NASS (gray numbers) databases. Values given in percent. 8.5 means that 8.5% of drivers reported in the database have height and weight that fit to a predefined range

Fig.1 presents the method of dividing the population used for purposes of this study. The x axis is weight expressed in kilograms and the y axis is height in centimetres. Horizontal lines at 165, 180 and 190cm level represent the height range borders and the curves represent BMI values of 22, 25 and 30 respectively. Gray dots represent height and weight of GIDAS drivers and triangles mark height and weight of 5th, 50th and 95th percentile Hybrid III dummies. In Fig. 1 and Fig. 2 BMI division lines were defined according to the WHO practice with one exception – BMI 22 is used for more equal distribution amongst the sub-groups. The division regarding BMI is as follows: less than 22 (underweight and lower normal range), 22-25 (upper normal range), 25-30 (overweight), 30 and over (obese).

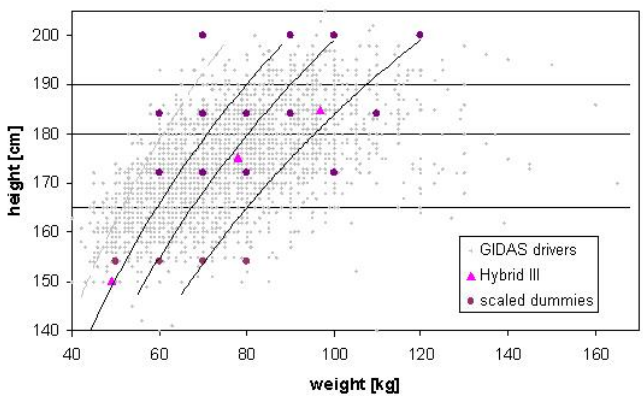

Fig. 3. Weight-height diagram, showing distribution of the drivers from GIDAS database (little dots), standard crash test dummies (triangles) and scaled dummies used for simulations (large dots). Horizontal lines separate different ranges of height, skew curves mark ranges of BMI 22, 25 and 30 (left to right).

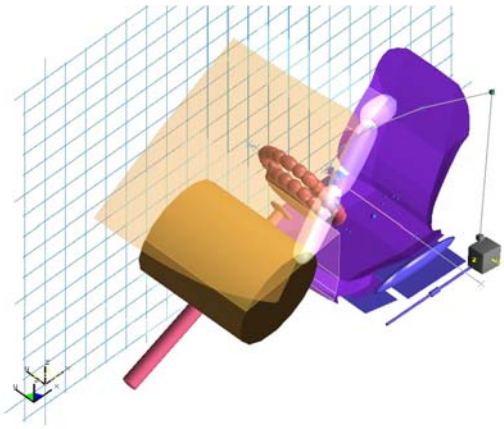

Fig. 4. The interior of the model car.

Computational Modeling

The numerical simulations were performed using MADYMO software with a module allowing for scaling a seated Hybrid III 50th percentile dummy to the required height and weight. Dimensions of the dummies were chosen in such a manner as to have one dummy in each BMI-height cell to make a comparison along the same height or weight possible. Fig. 3 above shows the distribution of the scaled dummies by height and weight.

A dummy was seated in the car in a position that would be comfortable for a driver. It was adjusted for each posture (height, weight) individually. Typical seating position was impossible due to non-standard dimensions of the dummies. The model car was a mid-size passenger car equipped with a three-point seatbelt with a pre-tensioner, belt force limiter and a standard size driver airbag with two stage inflator (Fig. 4).

III. RESULTS

The analysis of crash databases gave an interesting trend, showing that overall injury risk (MAIS 3+) increases with increase of BMI.

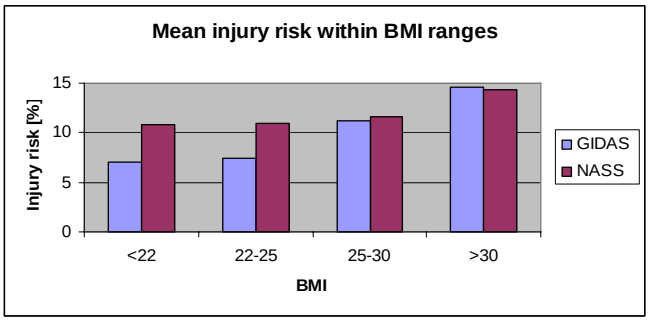

Fig. 5. Frequency of MAIS 3+ injuries increases with BMI in both databases. X axis is BMI range, Y axis – percent of drivers injured, related to the number of the drivers with same BMI range with MAIS 0+.

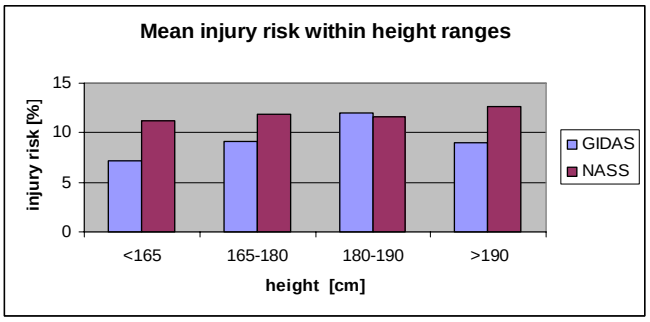

Fig. 6. There is no clear trend of dependence between height and risk of MAIS 3+ injuries. X axis is height range, Y axis – percent of drivers injured, related to the number of the drivers with same height range with MAIS 0+.

Other observed trends were an increase in chest injury frequency with increased BMI and an increase in head injury frequency with increased height. The same results were observed after performing numerical simulations for dummies scaled to various heights and weights. Head injury risk increased with height and chest injury risk increased with BMI. The main cause of head and chest injuries in the simulation was contact with the steering wheel. The tallest occupants had steering wheel-head contact (upper rim) or head-dashboard contact, despite airbag deployment. No clear trend was found when similar research was performed for weight-height cells.

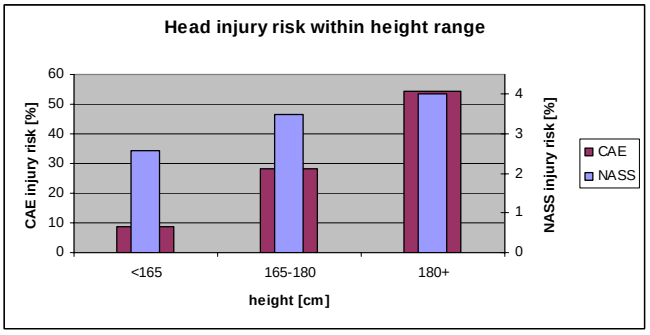

Fig. 7. Risk of AIS 2+ head injuries within the same height ranges – according to the division on BMI/height diagram. 180cm+ height group, which covers occupants both from 180-190cm and from 190cm+ ranges is due to small number of cases (only 23 MAIS 3+ injured drivers) in 190cm+ range. CAE means simulation, NASS means NASS database.

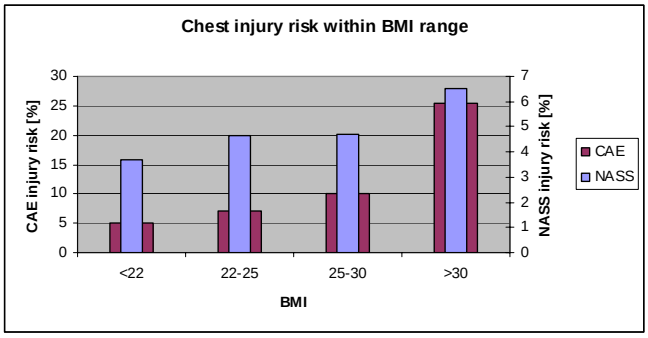

Fig. 8. Risk of chest injuries within the same BMI ranges – according to the division on BMI/height diagram. CAE values refer to AIS 3+, NASS values to AIS 2+ injuries, which is due to the injury curves available. CAE means simulation, NASS means NASS database.

Comparison of the crash database analysis and simulation results is based on the trends rather than the same criteria for the following reasons.. The values in Fig.7 and Fig.8 cannot be explicitly compared, due to differences between the real life and the simulation conditions. The crashes modeled during the simulations are high-speed ones whereas the database analysis covers a wide range of crash velocities, including low-speed collisions. The CAE model is equipped with state-of-art restraints, while restraints in the real world are varied. The real car fleet in the database is also much more varied than the model car used in the simulations. All these factors lead to noticeable differences in values of injury risk between the database and the simulations. However, the trends are comparable.

IV. DISCUSSION

The paper proposes a new approach to choosing parameters to measure reductions in injuries to certain body regions by means of adaptive restraints.

The study was limited to the driver side and to frontal crashes of passenger cars. The focus was on head and chest injuries, found to be most prevalent in frontal collisions, based on current literature. Differences in crash pulse were not taken into account in the statistical analysis. Simulations were performed for one pulse only (EuroNCAP ODB). The scaling procedure of Madymo dummies used for the calculations was not very accurate (unrealistic length of scaled femur, compared to Hybrid III dummies).

V. CONCLUSIONS

The analysis of the anthropometry of drivers from GIDAS and NASS-CDS databases, compared to WHO data, leaves an impression that up to 40% of drivers are not represented by any crash test dummy when considering height and weight parameters. This may lead to improper function of passive safety devices during the collision. A need for adjusting passive safety systems to individual requirements is clear.

Two parameters for occupant classification systems to measure adaptive restraint effectiveness are being proposed. To measure reduced injury risk, BMI is proposed for the chest and height is proposed for the head.

VI. ACKNOWLEDGEMENT

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