PROBLEMS ARISING WHEN USING INJURY SCALES IN THE BIOMECHANICAL INVESTIGATION WITH SPECIAL CONSIDERATION OF THE AGE INFLUENCE

by

R. Mattern, J. Barz, F. Schulz, D. Kallieris and Gg. Schmidt

Institute of Forensic Medicine
University of Heidelberg

Abstract

The quantitative recording of injuries as a main interest in the biomechanical research raises considerable problems when combined with physical measuring data. The injury scales used up to now, especially the AIS, are therefore exposed to considerable criticism. In the development of injury scales one principally has to distinguish between criteria of energy dissipation and life threatening. Both cannot be agreed upon in one scale degree. The age factor influences both the energetical injury tolerance and the prognosis. Therefore, when neglecting the age one has to reckon with faults in the expected correlation to physical data. That is very much true if the used scaling does not differentiate between energy dissipation and life threatening.

Through use of multiple regression analysis the influence of age on the results derived from tests on 212 belt protected cadavers which had been exposed to front collision was examined and scaled quantitatively. The according to OAIS criteria determined injury severity in the collision velocity range of 30 to 60 km/h revealed a 4.3 x greater influence due to age as to collision velocity.

The plastic deformation of the human body through mechanical energy is the biomechanical principal of injury. The quantitative analysis of causes and sequelae with the goal to determine tolerance levels of the body demands clearly defined and generally recognized systems of measurment. For an engineering-biomechanical assessment the units of classical physics can be used. Prevalent terms and concepts which are quite useful in medicine such as: uninjured - minor - moderate - severe - life threatening would seem to be for purposes of quantitative characterisation of a particular injury lacking in precision. As a result systems of injury description were developed, of which the AIS (Abbreviated Injury Scale)(STATES 1969, 1971, 1974, 1976) is most widely used.

In table 1 some of the important systems are represented and compared: principal differences in the number of ratings, the criteria for classification of the individual injuries and multiple injuries, for the overall injury severity and the definition of fatal injuries has been observed.

Publikation	Abbreviation	Scale Ratings			
		Uninjured	Not Life Threatening	Life Threatening	Fatal
1952 DEHAVEN		0	1 2 3	4	5
1956 HASBROOK	ACIR	1	2 3 4	5 6	7 8 9 10
1969 STATES	AIS	0	1 2 3	4 5	6 7 8 9
1971	AIS	0	1 2 3	4 5	6 7 8 9
1974	AIS	0	1 2 3	4 5	6
1976	AIS	0	1 2 3	4 5	6
1969 STATES	CRIS	1	2 3	4	5
1972 PATEL	ISL	0	1 2 3	4 5	6
1974 GÖGLER		0	1 (2) 3 4	5 6	Separately Listed
1974 1976 BAKER	ISS	$= \Sigma (AIS_{I}^{2} + AIS_{II}^{2} + AIS_{III}^{2})$		Rating Scores	0 - 75

ACIR = Automotive Crash Injury Research
AIS = Abbreviated Injury Scale
CRIS = Comprehensive Research Injury Scale
ISL = Indice de Sévérité des Lésions
ISS = Injury Severity Score

Table 1: Important injury defining systems

The most recent edition of the AIS (1976) differentiates between 6 severity levels which apply to both individual and the total effect of multiple injuries. A great advantage of the AIS is that in accordance with most important requirement for general use classifies in dictionary form nearly 300 types of injuries with their respective code numbers.

The criteria of classification of the individual injuries for expression in AIS values are both:

Energy dissipation and
Threat to life.

When determining the total effect of multiple injuries by the overall AIS (OAIS) the criterium threat to life and not that of energy dissipation is considered. The authors provided no detailed description of the OAIS in the case of multiple AIS-values.

The OAIS should be determined by a physician experienced in the treatment of trauma (STATES 1976). It involves a careful clinical-prognostical evaluation of pathophysiological overall effects of individual injuries for the body as a whole.

Already a deficiency of the OAIS is evident: we see how - and thus should be avoided - different examiners come to diverging judgements of the overall injury severity. Through close examination the authors themselves were able to determine that investigators who had examined the same groups of patients showed 80% agreement of rating.

A second deficiency of the OAIS and the AIS involves its ignoring the influence of age, which is not considered in injury rating. It must be expected that age is of considerable import in regard to the criteria of energy dissipation as well as that of threat to life (MATTERN 1978).

Much less force is necessary to produce a fracture of the femur in an older person as would be necessary to produce the same injury in a young man. For example the longitudinal breaking force of the isolated femur in a group of aged 16 to 30 was 2100 kp and decreases to 1600 kp for persons aged over 60 years (HAHMANN 1976). In addition to differences in the breaking load the trauma itself is often a life threatening injury when the aged are involved, whereas in the case of adolescents there is a generally no threat to life. The AIS disregarding these essential differences rates the uncomplicated fracture of the femur as code 2.

For the isolated rib fracture the AIS-code 2 is also applied, although for this injury approximately 1/50 of the force, which is necessary to cause a femur fracture, is required: in dynamic loading of isolated ribs 40 kp was measured in the age group 16 to 30 years and 20 kp for those over 60 years (VETRE 1977).

These examples of the AIS-assessment of injuries to isolated body parts must cause one to doubt the efficacy of this system of injury classification: Does the AIS-code provide reliable representation of the magnitude of mechanical influence?

Doubts as to the applicability of the AIS are more relevant when the entire body is loaded. First of all it is questionable, if the tolerance levels of young man and older persons evidence the same relationship as was gained through comparison of the data from tests involving isolated body parts.

Through statistical analysis of the results of 212 standardized frontal collisions involving belted cadavers of varied age (Fig.1) we were able to compute with multiple regression-analysis (REIDELBACH and SCHMID 1976) the relative weight of the age factor and other anthropometrical data in relation to the physically defined input factors.

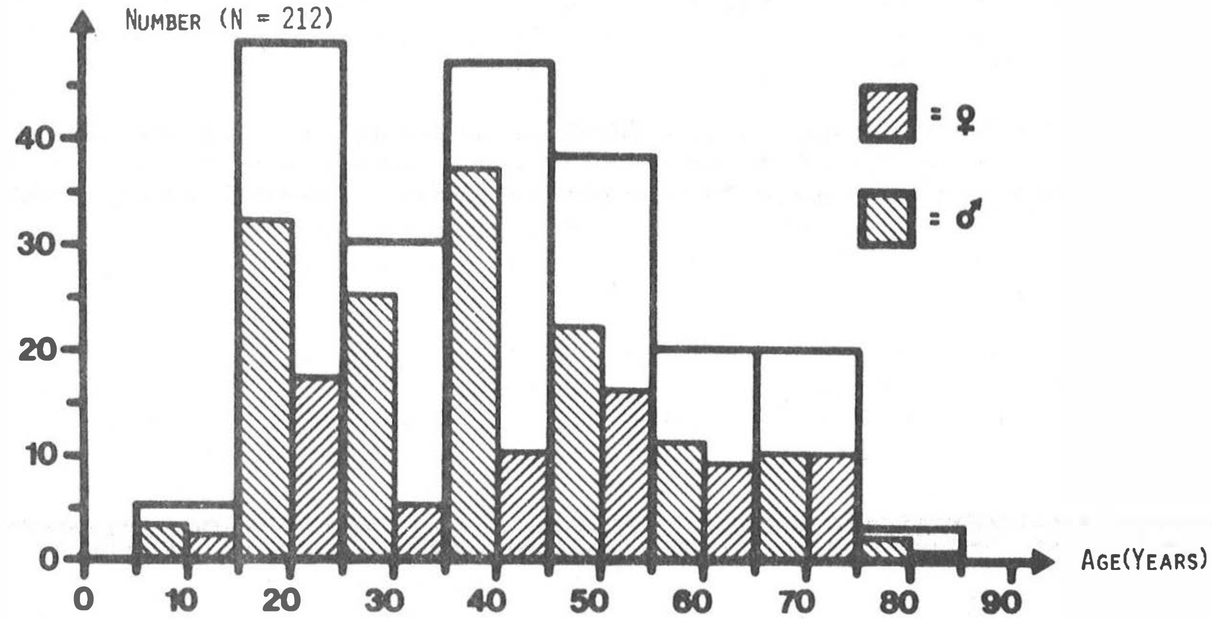

Fig. 1: Distribution by age

These were sled tests with decelerations of 10 to 25 g and collision velocities of 30 to 60 km/h. In addition to these input defining factors of the mechanical event, 15 physically measurable and anthropometrical data were computed (SCHMIDT et al. 1978).

If one records the number of rib fractures as a function of age and calculates by means of multiple regression analysis functional curves of the velocity groups individually, one arrives at the graphic representation shown Fig. 2a. All four functional curves show a considerable increase in the number of rib fractures with increase in age.

If we chose to reverse the representation and the number of rib fractures are drawn as a function of the velocity (Fig. 2b) we see with increase in velocity the same increase in the number of rib fractures. Accordingly the influence of age is in this relationship equal to the significance of the velocity

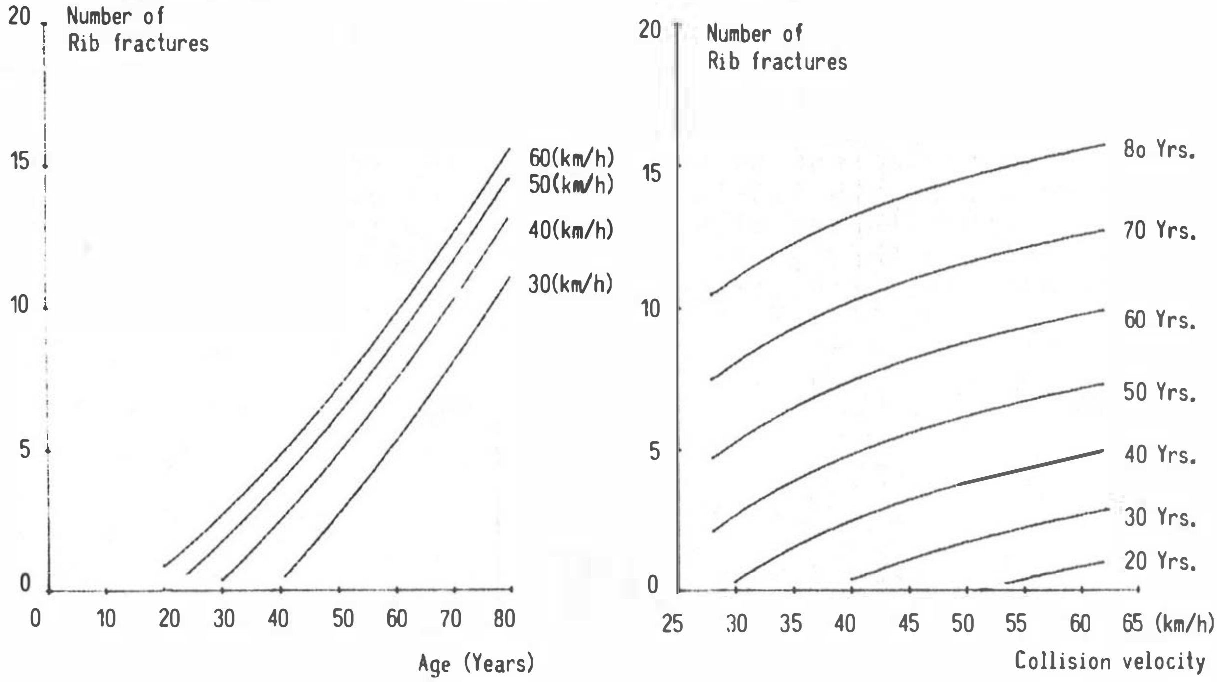

Fig. 2: Rib fractures as a function
a: of age b: of collision velocity

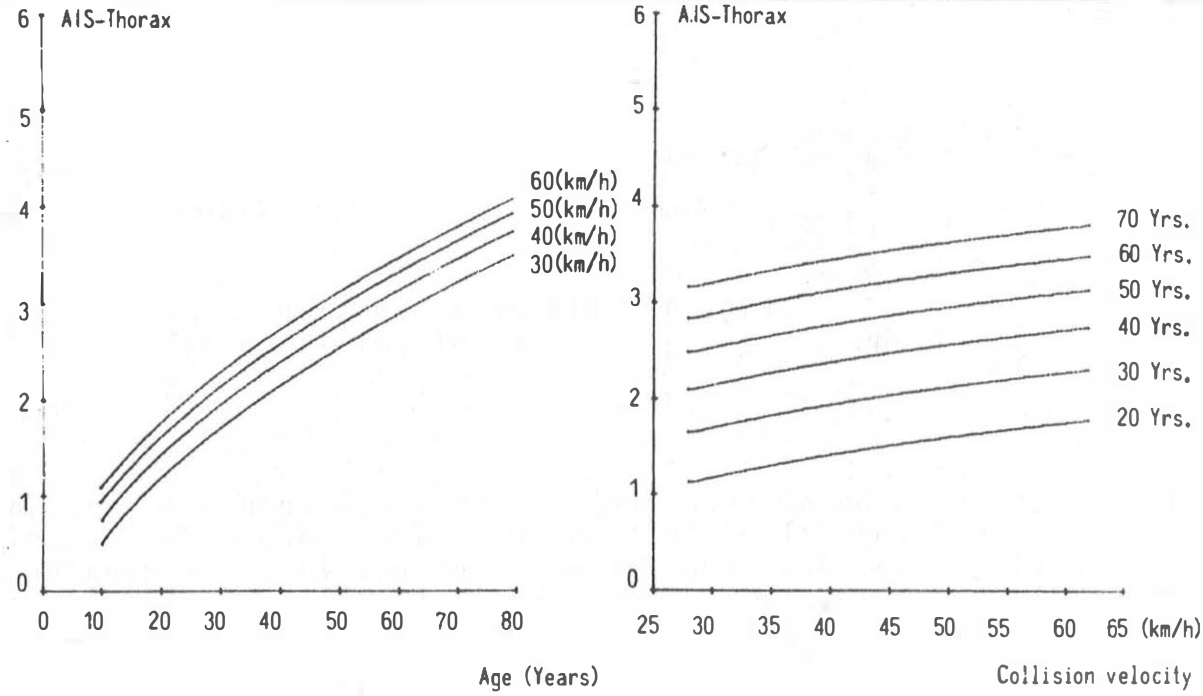

Fig. 3: AIS-thorax as a function
a: of age b: of collision velocity

If we code the rib fractures according to the AIS rating system and create a "Regional AIS-Thorax" - aside from rib fractures the AIS-Thorax will cover sternum fractures, clavicle fractures and injuries to the internal organs of chest, so that more serious degrees of injury are reflected in the code rating as would be the case if the rib fractures were coded separately - by employing multiple regression analysis, it becomes evident that, by representing the AIS-Thorax as a function of the collision velocity, that the results are 1.5 x more influenced by age than by collision velocity. At the same time age is demonstrated to be the most important factor (Fig. 3a,b).

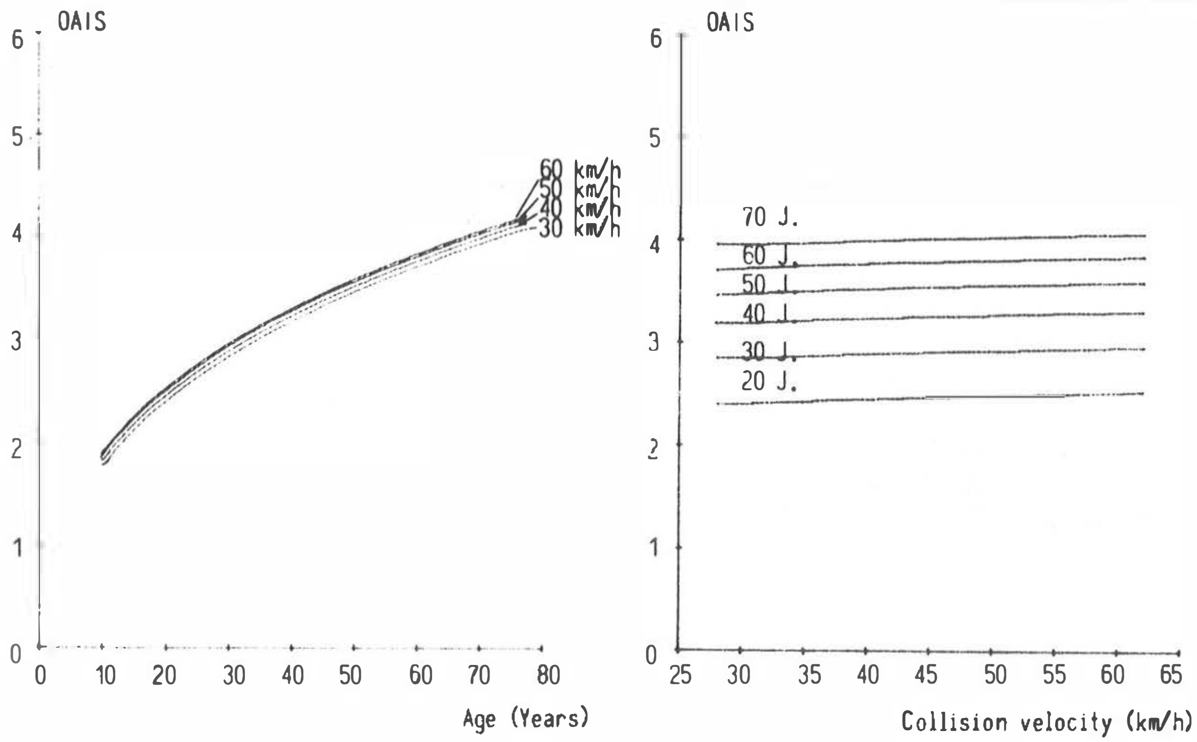

Fig. 4: OAIS as a function
a: of age b: of collision velocity

Age is shown to be of even greater influence when all injured body areas of the belted test subjects are represented by an OAIS rating (Fig. 4a). The influence of age is 4.3 x greater than the collision velocity and tops the list of all input factors. Since the function curves of the OAIS for persons over the age of 30 for velocities of 30, 40, 50 and 60 km/h lie very close together, an increase of the collision velocity from 30 to 60 km/h in the age group 40 years is accompagnied by an increase of the degree of injury of less than 1 AIS-degree.

This becomes evident in the graphic representation of the result, if in the diagramm OAIS as a function of the collision velocity is recorded for the various age groups (Fig. 4b). One can see clearly that the degree of injury is hardly influenced, when the collision velocity is increased from 30 to 60 km/h. In the same diagramm the sled deceleration for the entire velocity range is 16 g and correspond to the mean value arrived at through statistical evaluation of the tests.

Conclusions

From a medical standpoint the mechanical tolerance limit of man is to be defined in terms of injury. In our view it is expedient to establish this limit between 2 groups of injury severity:

> The first group comprises severe injuries, which according to medical experience are not life threatening.
>
> The second group includes those injuries, for which a fatal end is not uncommon.

If the OAIS is used according to this definition, the tolerance limit lies between OAIS 3 and OAIS 4 (BARZ et al. 1978).

From a biomechanical standpoint we are interested in the boundry values of mechanical input, under which the tolerance limit is reached.

Our frontal collision tests of belted occupants show that estimations of boundry values which have not considered the age of the test subjects, are of questionable relevance and should no longer be accepted. If the tolerable velocity, at which an injury of more than OAIS 3 is not probable, is sought, then it becames imperative, to include the age factor, when one considers that age influences the degree of injury to a 4.3 x greater extent than collision velocity.Whereas a thirty year old can tolerate a 60 km/h collision at a deceleration of 16 g without the OAIS being any higher than 3, the border of marginal velocity for the seventy year old lies well below 20 km/h.

On the other hand if one uses a Regional AIS-Thorax to determine the tolerance level, the severity of injury shows a better correlation with collision velocity than when the OAIS is employed.

If the number of rib fractures is the injury parameter, which is to be predicted on the basis of collision velocity, the best correlation is realized.

A prediction carries the most weight, when the injury parameter represent body structures - such as the ribs in the loading of belt-protected occupants - which are major supports of the body's mechanical stability.

Undifferentiated representations in OAIS ratings cannot provide acceptable correlation with the energy dissipated.

This is especially so, when we consider, that the OAIS code rating 3 includes injuries, which a young indiviual always survives but for an older person often prove fatal. The same injury in an older person should receive the OAIS 4; the tolerance limit of a given mechanical input must be reduced further in order to obtain a comparable OAIS value for the criterium "life threatening".

The results obtained from cadaver tests cannot provide quantitative description of this problem.

In according with our experience in biomechanic research significant correlations between mechanical input and AIS ratings can only be expected, when the test subjects are homogenous in reference to age and body constitution (on which we will report separately in the near future).

These conditions cannot be realized in the automotive traffic environment. It is time we gave more thought to the premises of the AIS-system and considered if it would not be better to redefine the protective criteria of mechanical input with reference to the tolerance limits of that half of the population most susceptible to serious traumatic injury (MATTERN 1978).

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