THE INFLUENCE OF THE REPRODUCIBILITY OF ANTHROPOMORPHIC TEST DEVICES ON INJURY RISK FUNCTIONS

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ABSTRACT

The design of advanced ATD is moving towards being more human-like and therefore is more complex. More complexity generally leads to more degrees of freedom, the uncertainty of an ATD as a measurement tool rises. The uncertainty of a measurement tool is described by the repeatability and the reproducibility.

An ATD alone can only provide measurements. These measurements do not directly reveal the safety level of a vehicle in a crash test. By using a mathematical function, a so-called injury risk function, the ATD measurements can be related to injury risks. The injury risk is a measure to show how well a vehicle protects the occupant or vulnerable road user. The influence of a poor repeatability or reproducibility on the calculation of the injury risk is obvious. For a given measurement variability it is simple to check the associated risk variability by putting the values in the relevant injury risk function. Much less obvious is the effect of poor repeatability and reproducibility on the injury risk function itself. The injury risk function for an ATD is typically a combination of PMHS test results and matched ATD test results. This simple fact reveals that the repeatability as well as the reproducibility of an ATD can already influence the development of the injury risk function and not only the calculation of the injury risk.

This study aims to get a basic understanding how the measurement variability of ATD can influence the resulting injury risk function. The study uses data from real repeatability and reproducibility tests with the THOR-50M. For reasons of simplicity the study focuses on the influence of the reproducibility, that is, a perfect repeatability is assumed. Two theoretical PMHS data sets are used to study the reproducibility influence: one with current status data (left and right censored data) and one with exact data. In addition, two different methods for the mapping of ATD measurements onto PMHS results in the risk function development are deployed. This study shows that injury risk curves depend on ATD reproducibility. Current injury risk function development is only reliable with a good ATD reproducibility. Data of THOR-50M used in this study reveals that the current injury risk function development procedure should consider the reproducibility of the ATD.

The study used only one data set for the reproducibility of the ATD which limits the generality of the results. In addition only a theoretical and simple injury risk function was applied. More complex injury risk functions with additional co-variants or complex criteria may lead to diverging results. The general effect that the reproducibility is influencing the injury risk function is unaffected.

As reproducibility cannot be easily improved because of technical and practical reasons, a methodology needs to be developed that includes the effects of reproducibility in the calculation of injury risk curves.

INTRODUCTION

Modern Anthropomorphic Test Devices (ATDs) are getting increasingly more complex with more and more mechanical degrees of freedom. A mechanical system with more degrees of freedom typically gets less predictable. For the same reason ATDs with a higher complexity have the tendency to show more measurement uncertainty.

The assessment of vehicle safety is usually done by using an ATD in a prescribed crash test and a specific measurement or indicator, the so-called injury criterion (e.g., R_{max}, a injury criterion regarding thorax injuries). For each injury criterion value determined with an ATD there is an associated injury risk which is typically calculated with a specific function - the injury risk function (IRF). The smaller the calculated injury risk the better the safety rating of the vehicle. It is obvious that with a higher uncertainty of the injury criterion value the vehicle safety rating becomes less precise. Therefore, attention needs to be paid to a high precision of the injury criterion measurement of an ATD.

Regarding the measurement precision two components need to be distinguished: repeatability and reproducibility. With respect to ATDs the repeatability is the precision of measurements with one ATD whereas the reproducibility describes the measurement variance between two or more ATDs of the same type. More precisely the reproducibility is the difference between the mean injury criterion responses of two ATDs in repeated tests.

If two ATDs of the same make measure different criterion values in equal vehicle tests, the calculated risks will be different too - assumed the same injury risk function was used. Consequently, those two ATDs will lead to two different ratings of the vehicle safety. However, this obvious adverse result of a poor reproducibility isn't the only negative effect. The injury risk function itself depends on ATD measurements and thus might be influenced by the ATD reproducibility.

FUNDAMENTALS

Some basic knowledge about the principles of developing ATD injury risk functions are needed to be able to understand the implication of a poor reproducibility on the injury risk assessment with an ATD. An ATD can only provide measurements which are used to determine injury criterion values. These injury criterion values do not reveal the injury risk by itself. Only by relating the ATD injury criterion values to injury risks, an ATD can show the risk of injury. In the present paper relating the ATD injury criterion values to injury risks is called mapping. To apply the mapping each test must be performed at least with one PMHS (Post Mortem Human Subject) and one ATD in the exact same way. These kind of tests are often called matched pair tests. Mapping combines PMHS test results and matched ATD test results to build a ATD injury risk function. That is, an injury risk function that can be used with measurements from the same type of ATD that was used in the matched pair tests. To obtain a reliable injury risk function, the biomechanical tests are typically performed with many PMHS because the test responses of different PMHS of a population normally differ substantially. The matched ATD tests are mostly performed only with one or a very few different ATDs of the same type.

Mapping

The mapping of ATD injury criterion values to PMHS injury risks can be done in different ways. Basically, there are two fundamentally different mapping methods:

- mapping of ATD injury criterion values onto PMHS injury responses - further on called injury mapping.
- mapping of ATD injury criterion values onto PMHS injury criterion values - further on called criterion mapping.

The typical ATD injury risk function development process using injury mapping is (figure 1):

1. Perform biomechanical tests on a sample of PMHS.
2. Record the (binary) PMHS injury responses (e.g., injury severity $\geq$ AIS3: yes or no).
3. Repeat the PMHS tests with an ATD.
4. Measure the ATD injury criterion values.
5. Calculate an ATD injury risk function using the ATD injury criterion values and the PMHS injury responses.

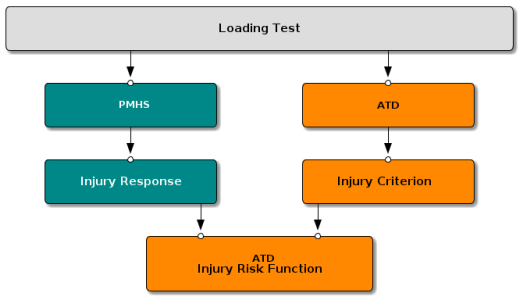

Figure 1: Typical ATD injury risk function development process using injury mapping. ATD injury criterion values are used together with the PMHS injury response to calculate an injury risk function for the ATD.

Criterion mapping is realised by using a so-called transfer function. The typical ATD injury risk function development process using criterion mapping is (figure 2):

1. Perform biomechanical tests on a sample of PMHS.
2. Record the (binary) PMHS injury responses (e.g., injury severity $\geq$ AIS3: yes or no).
3. Measure the PMHS injury criterion values.
4. Calculate a PMHS injury risk function using the PMHS injury responses and PMHS injury criterion values.
5. Repeat the PMHS tests with an ATD.
6. Measure the ATD injury criterion values.
7. Calculate a transfer function to transform the ATD injury criterion values to PMHS injury criterion values (e.g., using a linear regression between PMHS and ATD injury criterion values).
8. Build the ATD injury risk function by using the transfer function inside of the PMHS injury risk function (i.e., substituting the PMHS criterion value by the transferred ATD criterion values).

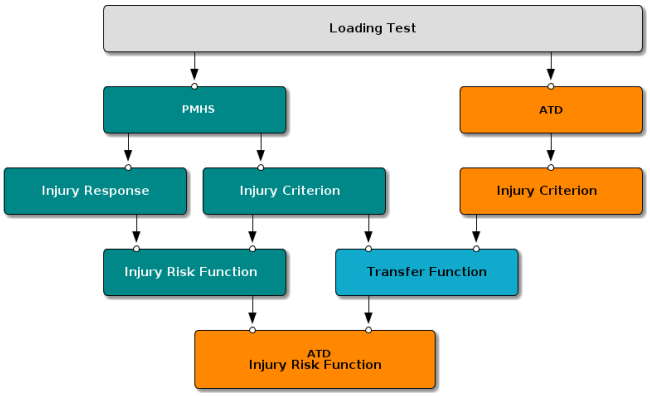

Figure 2: Typical ATD injury risk function development process using criterion mapping. ATD injury criterion values are converted to PMHS criterion values with a so-called transfer function to build the injury risk function for the ATD.

It's important to note that different mapping methods lead to different injury risk functions on principle. By using injury mapping, the injury risk function shows the injury risk of a random person with respect to an ATD injury criterion value. By using criterion mapping, the injury risk function shows the injury risk of a person with a mean injury criterion response with respect to an ATD criterion value. The following example illustrates the above statement about criterion mapping. An ATD measures a chest deflection of 10 mm in a sled test. According to the injury risk function - which was built by criterion mapping - this 10 mm chest deflection is associated with an injury risk of 20%. This does not imply that a random person in this sled test has an injury risk of 20%. It rather indicates that there is an injury risk of 20% for a person which has an average chest deflection response. Only a subgroup of all the people will have a 20% injury risk, those with an average chest deflection response. The reason for this is because the criterion mapping using a conventional transfer function maps the ATD injury criterion values to the average PMHS criterion values. With this approach an ATD injury criterion value is associated with an average PMHS injury criterion response and thus the ATD injury risk function shows the injury risk of a PMHS with an average injury criterion response.

It should be noted that there are more possibilities to transfer ATD injury criterion values to injury risks. The methods described above are the most frequently used ones.

Data Censoring

To relate ATD injury criterion values to injury risks, either by injury mapping or by criterion mapping, data from PMHS tests are indispensable. Without PMHS data it isn't possible to predict the risk of injury by ATD measurements. Especially the information about the injury response of a PMHS is indispensable. More precisely the onset of the injury in terms of an injury criterion needs to be known. This onset of the injury is the so-called biomechanical tolerance limit of a person and the distribution of biomechanical tolerance limits of a PMHS sample describes the injury risk function.

Unfortunately, the biomechanical tolerance limit often can't be measured directly in a biomechanical test because the injury criterion and the injury outcome are recorded independently at different times and can't be related exactly with a measured injury criterion value. This specific form of uncertainty about the actual biomechanical tolerance limit is called censoring. Biomechanical test data often is censored.

For the correct calculation of an injury risk function, it is important to know whether the injury criterion value was measured exactly at the onset of injury. If an injury was observed in a biomechanical loading test, the injury criterion value measured in this loading test exceeded the biomechanical tolerance limit of the test subject. However, often it's unknown how much the measured injury criterion value exceeded the biomechanical tolerance limit. Such data is called left censored data. If no injury was observed on the subject, the injury criterion value didn't exceed the biomechanical tolerance limit of this subject. If it's unknown how much lower the measured injury criterion value was compared to the biomechanical tolerance limit the data is called right censored data. If all data in a data set is either left or right censored, the data is called current status data. That is, the (binary) injury status of a PMHS at a measured injury criterion value is known. It is known if the subject has an injury of a prescribed severity or not but the injury criterion value at the onset of the injury - at the biomechanical tolerance limit - is unknown. If one individual was tested twice, one test without injury and a second test with injury. The interval in which the biomechanical tolerance limit is located is known. Such data is called interval censored data. In case the injury criterion value marks the onset of the injury the data is called exact data, data without any censoring. Figure 3 schematically shows all possible data censoring types.

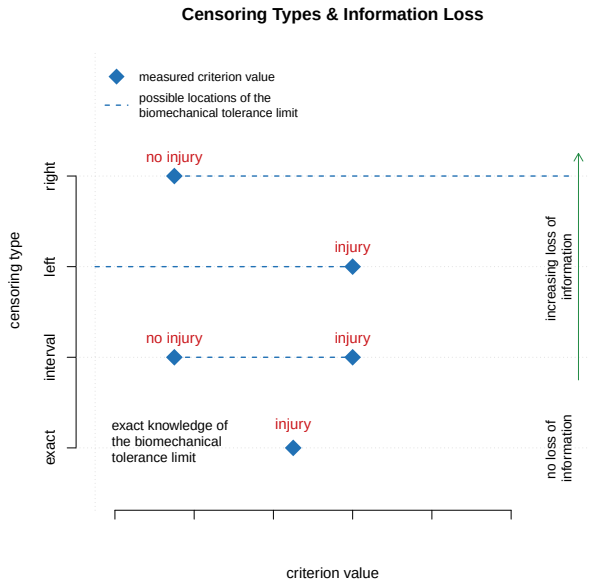

Figure 3: Different types of data censoring.

OBJECTIVES

Injury risk functions which are used with ATDs are typically built by using ATD test results, more precisely by using injury criterion values determined from ATD measurements. Thus, the measurement uncertainty of an ATD is in principle able to influence the ATD injury risk function. This raises the question if this fact needs to be taken into account in the development process of injury risk functions for ATDs. As described above, the measurement uncertainty - the repeatability and reproducibility - of an ATD is interconnected with the injury risk function for the ATD. Thus, the repeatability and reproducibility of an ATD might affect its injury risk function such that the safety ratings based on tests with this ATD are unreliable.

This study is focused on the effect of the reproducibility on the injury risk function to get a better basic understanding of its influence on the injury risk function and aims to:

1. illustrate how the reproducibility of ATDs influence the resulting injury risk function,
2. elucidate the role of the injury risk function development method and data censoring, and
3. discuss the consequences of the results.

METHODS

This study is a theoretical study. All data are theoretical data except the reproducibility data of the ATD. The reason to use theoretical data was to be able to systematically manipulate characteristics of the data and observe the effect. The theoretical but realistic biomechanical test data were generated by simulating the PMHS sampling and all subsequent steps like they are performed in a real injury risk function development process. A data set resulting from this data generation process can be found in the appendix of the paper (table 3). Based on the simulated biomechanical test results an injury risk function can be calculated (all calculations have been performed with the statistical software R [1]). The resulting injury risk curve depends on the random PMHS sample - like in reality. On the left side of figure 4 this randomness of the injury risk curve is illustrated by presenting the injury risk curves from five different theoretical PMHS samples of the same sample size. On the right side of figure 4 the injury risk curve based on one PMHS sample and its underlying theoretical biomechanical test results are shown. Not only the randomness due to sampling of test subjects are replicated by the data generation process but also the variability of the injury criterion values with respect to different test subjects. PMHS test results are shown for each defined load case in figure 5. Eight load cases and ten PMHS per load case were utilised in the analyses. Four different variabilities of PMHS injury criterion responses were used to study its effect and called "No", "Low", "Mid", and "High" variability.

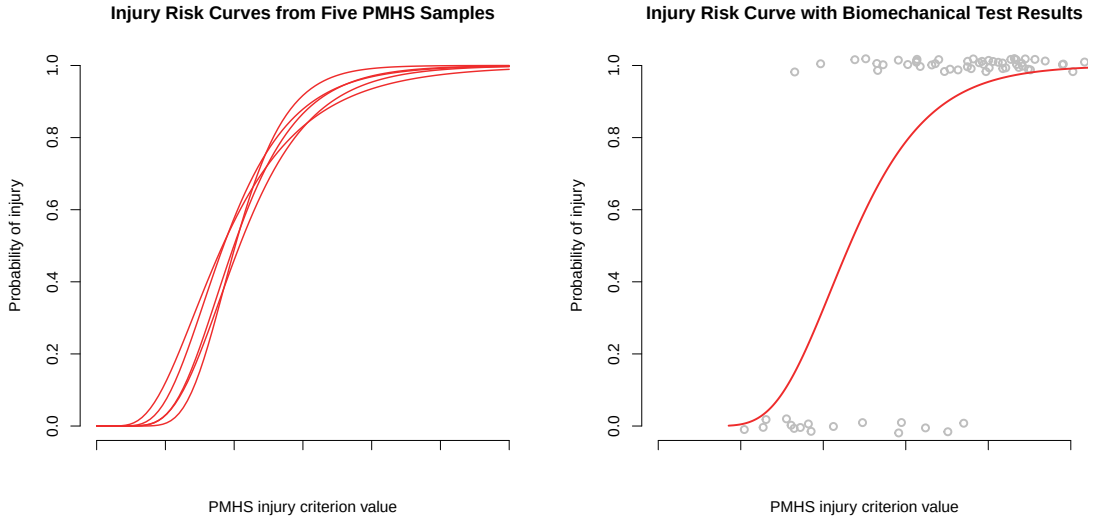

Figure 4: Left: Injury risk curves based on different theoretical PMHS samples (same sample size); right: Biomechanical test results and injury risk curve from one theoretical PMHS sample (points shown on top of the graph are injury cases, points at the bottom are non-injury cases).

Like the PMHS test data, the ATD injury criterion values are theoretical data. They are defined to represent the mean injury criterion response of the underlying PMHS population for each load case. The injury mapping was performed by using the eight ATD injury criterion values defined by the eight load cases with the censoring status of the eighty PMHS test results in a survival analysis. The criterion mapping was done by using a transfer function defined as the linear regression between ATD injury criterion values and PMHS injury criterion values. Figure 5 shows the linear regressions for the four different PMHS injury criterion variabilities.

With the procedures described above it is possible to generate realistic biomechanical test data, perform the mapping of ATD injury criterion values onto PMHS results, and calculate the ATD injury risk function. The theoretical

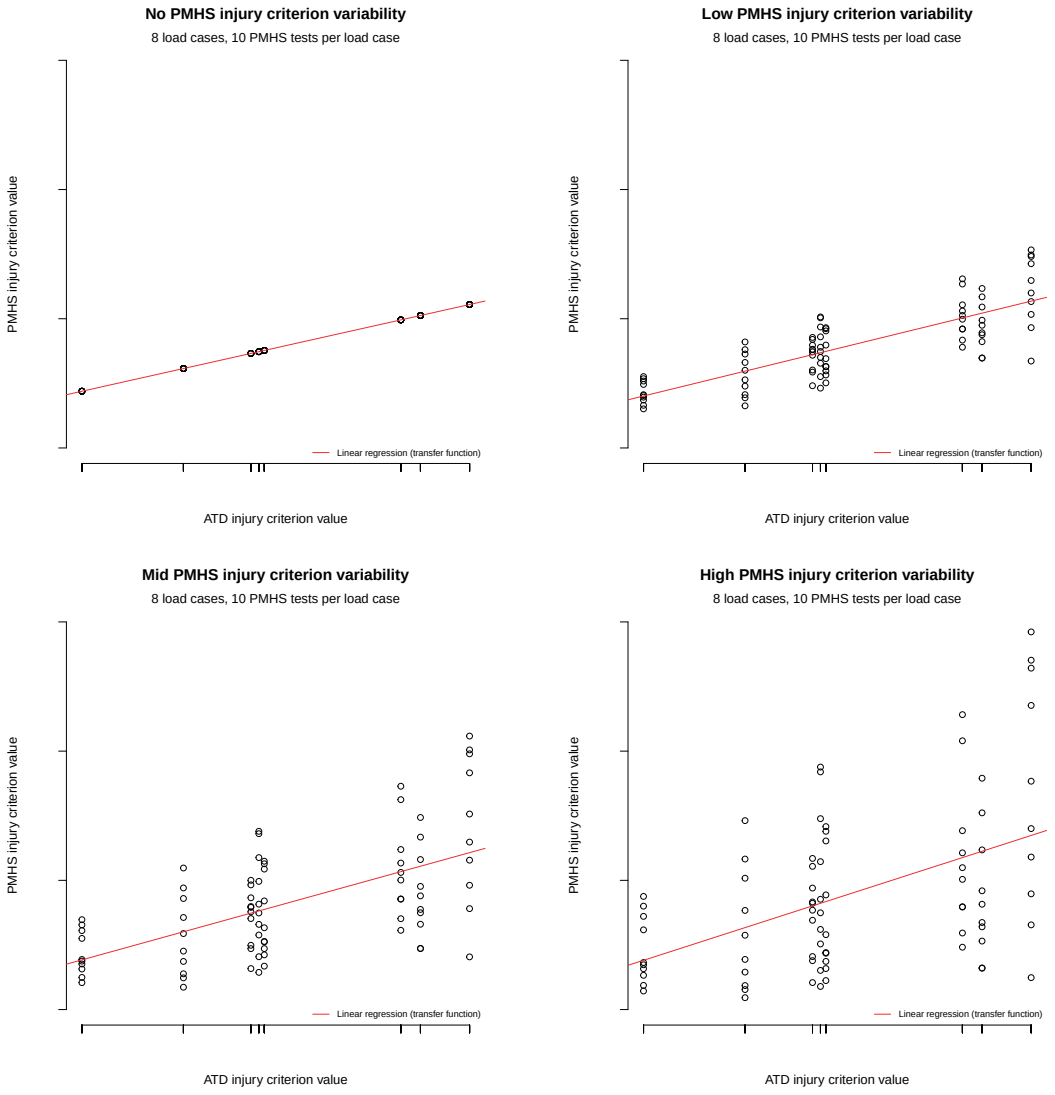

Figure 5: Four theoretical data sets with different PMHS injury criterion variabilities and the associated transfer functions.

PMHS and ATD test data is subsequently used to study the effect of the reproducibility of ATD measurements on the resulting ATD injury risk curve. Since this study focuses on the reproducibility of ATDs and for reasons of simplification a perfect repeatability is assumed. Simulated test data from one single ATD are used for the mapping between ATD and PMHS results.

To show the effect of ATD reproducibility on the resulting injury risk function two hypothetical ATDs were defined and used for the calculation of ATD injury risk functions. Although this is a theoretical study, realistic data regarding the ATD reproducibility are used for the definition of the two ATDs. The Partnership for Dummy Technology and Biomechanics performed so-called repeatability and reproducibility tests (R&R tests) with seven different 50^{th} percentile male THOR dummies (THOR-50M) [2][3]. The same test was performed multiple times with each THOR-50M. Table 1 shows the number of repeated tests for each THOR-50M.

Table 1: Number of tests performed with each THOR-50M

ATD	Number of performed tests
THOR-50M A	3
THOR-50M B	3
THOR-50M C	6
THOR-50M D	3
THOR-50M E	3
THOR-50M F	5
THOR-50M G	6

The THOR-50M was a THOR-50M Standard Built Level B (SBL-B) with THOR-LX legs. The dummies were from two different manufacturers. The simplified vehicle-like test environment included a rigid seat, a rigid dashboard with deformable knee bolster, a deployed and pressurized airbag, and a 3-point belt with pre-tensioner and single-stage force limiter. The boundary conditions of the test were derived from a 0° degree full-width rigid wall test. The crash pulse was downscaled because of the rigid parts of the test environment. The positioning of the THOR-50M was done with high precision to avoid any influence of different dummy positions on the test outcome. Therefore, the variance in real vehicle crash tests might be higher. The repeatability and reproducibility data included a total of 29 test observations. For each test the injury criterion R_{max} have been determined. From these data set the mean and standard deviation of the mean R_{max} values of the seven ATDs are used to define a Normal distribution. Based on this Normal distribution a hypothetical ATD with a two standard deviations higher than the mean injury criterion measurement was defined and called ATD-HIGH. A second hypothetical ATD called ATD-LOW was defined by a two standard deviations lower than the mean injury criterion measurement. According to the so-called empirical rule (equation (1)) these two hypothetical ATDs contain ninety five percent of all ATDs with respect to the R_{max} measurement. Therefore, the comparison of ATD-HIGH and ATD-LOW represents a reasonable spread in regards of the reproducibility but at the same time is not the worst case. The left graph in figure 6 schematically depicts the definition of the two theoretical ATDs with respect to the distribution of the average injury criterion measurements of different ATDs.

$$P(\mu - 2\sigma \leq X \leq \mu + 2\sigma) \approx 95\% \tag{1}$$

The approach to get theoretical but realistic injury risk functions as described above is only valid for current status data. Exact data is measured at the onset of the injury and represents the biomechanical tolerance limit of the PMHS. Thus, every test response is an injury case (with an injury of a certain severity). Dynamic ATD tests in which the ATD injury criterion value is determined independent of the injury onset of the PMHS can't be used for injury mapping with exact biomechanical test data. For each load case there is one ATD injury criterion value which must be mapped to some matched PMHS responses and those are all injury cases. Thus, the distribution of the ATD injury criterion values determines the injury risk function. However, the ATD injury criterion values are independent of the biomechanical tolerance limits of the PMHS. So there is no meaningful relationship between the ATD injury risk function and the PMHS injury risk. For this reason injury mapping with exact data isn't possible. To perform criterion mapping with exact data, ATD injury criterion values are needed that are linked to PMHS injury criterion values. With these data a transfer function can be calculated and used to transfer the PMHS injury risk function into a ATD injury risk function. The only difference to criterion mapping with current status data is that the PMHS injury risk function is built with exact data. The ATD to PMHS mapping is equal for current status data and exact data. For that reason it is not

necessary to study the effect of ATD reproducibility with exact data separately.

It has to be emphasised that the results of the simulation study are used to illustrate the effect of ATD reproducibility on the ATD injury risk function by way of example. The used method leads to realistic but not real data and is based on some unproven assumptions, for example the variability of PMHS injury criterion values with respect to a load case. Thus, the results and conclusions can't be generalised and might not fit to other data. Different and especially more complex injury criteria, the consideration of the ATD repeatability, and the use of covariates in the injury risk function might lead to other conclusions. To prevent an over-interpretation of the results all diagrams are without values.

RESULTS

The evaluation of the mean R_{max} values of the seven THOR-50M revealed that in this specific test data sample a ATD-LOW would measure 15% lower R_{max} values than a ATD-HIGH if they are defined as described in the methods section (right graph of figure 6). Based on this result from real THOR-50M R&R tests the injury criterion values of ATD-LOW were defined to be 15% lower than the injury criterion values of ATD-HIGH. In this example the 15% difference in injury criterion values corresponds to a difference between the mean plus two standard deviations and the mean minus two standard deviations (left and right graph of figure 6). For other injury criteria or other data samples a difference of ± 2 standard deviations from the mean might be higher or lower than 15%.

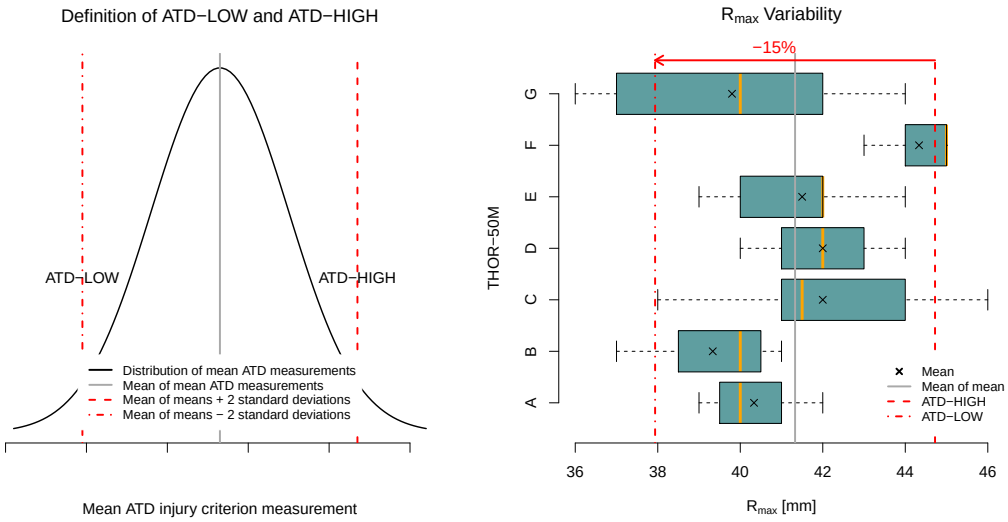

Figure 6: Left: Generic definition of ATD-LOW and ATD-HIGH; right: Distribution of R_{max} criterion values of seven THOR-50M dummies and the calculated mean R_{max} values of ATD-LOW and ATD-HIGH.

Before presenting the results regarding the main objectives of the study, more general results from the simulated injury risk function development are shown in figure 7 and 8. Figure 7 demonstrates that an ATD injury risk curve in principle depends on the method used to map ATD measurements to PMHS results. This result is in line with the theoretical considerations presented earlier in this paper. The actual difference between injury risk curves built with different mapping methods depends on the PMHS injury criterion variability as demonstrated in figure 7. Only if the injury criterion values of different PMHS do not vary in the same load case both mapping methods result in the same injury risk function (upper left plot of figure 7). However, it seems unrealistic that PMHS injury criterion values do not vary between different subjects. The difference between ATD injury risk curves built with different mapping methods do not only depend on the PMHS injury criterion variability but also on the actual PMHS sample as the results shown in figure 8 reveal.

With these general findings about factors of influence regarding the ATD injury risk curves the main objective of the current study, namely the influence of ATD reproducibility on the ATD injury risk function, can be addressed. As described in the methods section, two ATDs have been defined with different mean injury criterion responses. Using the same biomechanical test data with the results from these two ATDs leads to two different ATD injury risk

functions. Figure 9 shows the ATD injury risk functions built with the injury criterion values of ATD-HIGH and ATD-LOW. The risks are higher with the injury risk curve based on ATD-LOW compared to the risks for ATD-HIGH. No matter if the PMHS injury criterion values of the PMHS sample possess "no", "low", "mid", or "high" variability the injury risk curve built with the ATD-LOW is located left of the injury risk function based on ATD-HIGH (figure 9). Furthermore, the injury risk curves of ATD-LOW and ATD-HIGH are equally affected by the mapping method. The difference between the injury risk curves of ATD-LOW and ATD-HIGH is independent of the actual PMHS sample used in the development of the ATD injury risk curve (figure 10) and is as big as the difference between ATD-LOW and ATD-HIGH injury criterion measurements (figure 11).

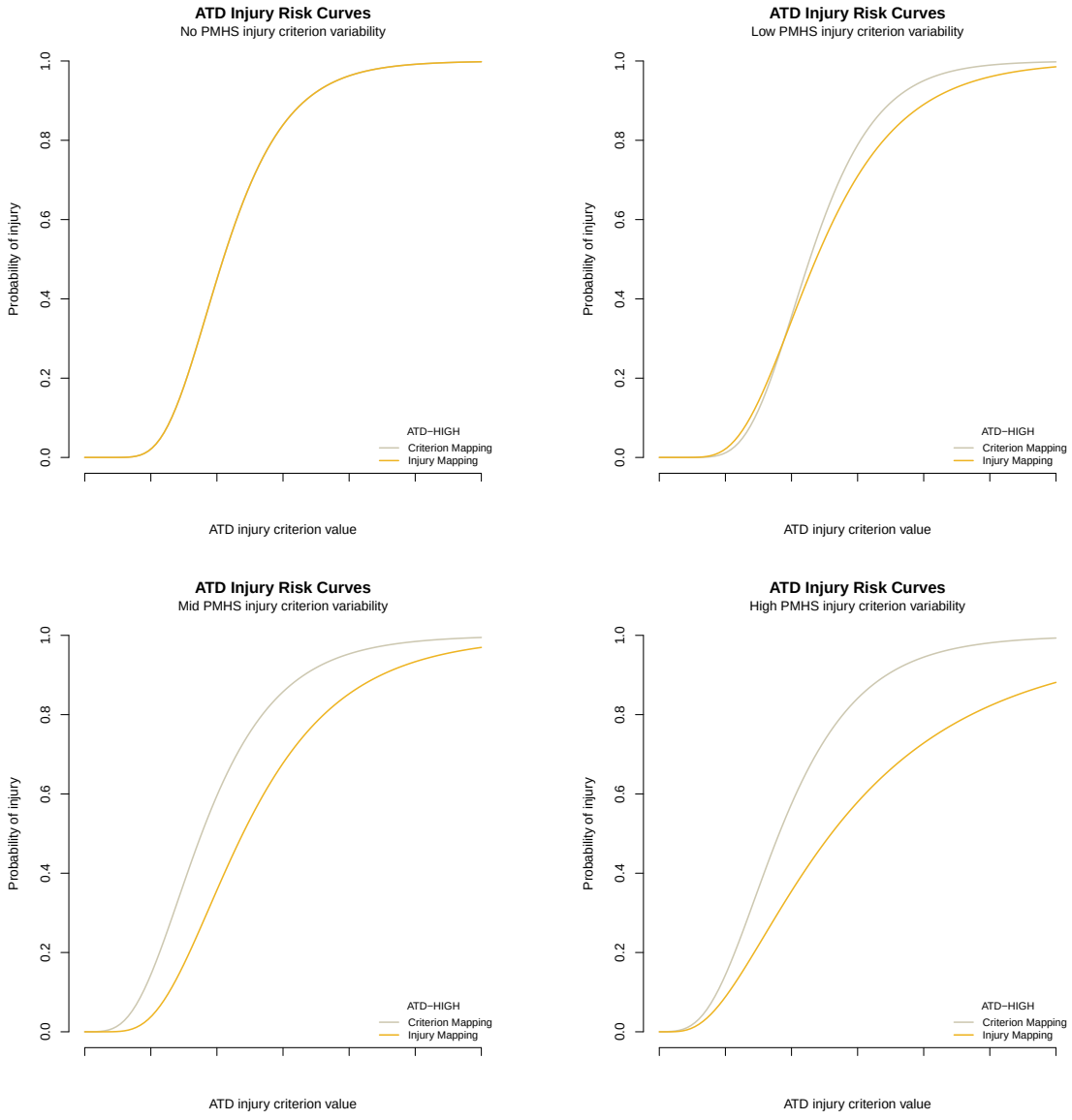

Figure 7: Influence of different mapping methods and different PMHS criterion variabilities on the ATD injury risk curve. All curves are based on one PMHS sample.

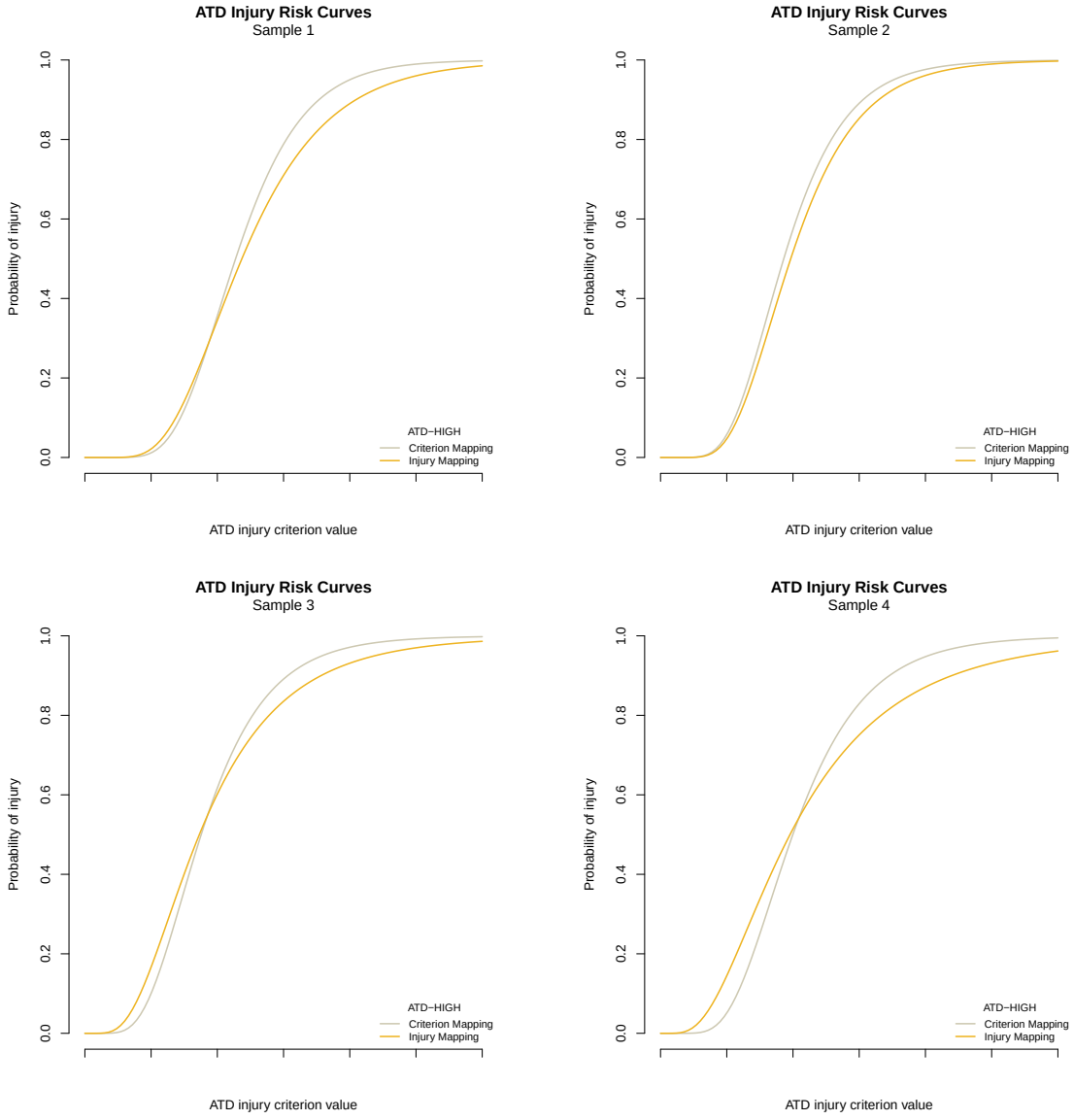

Figure 8: Effect of different PMHS samples on the ATD injury risk curves built with different mapping methods. All curves are based on mid PMHS injury criterion variability.

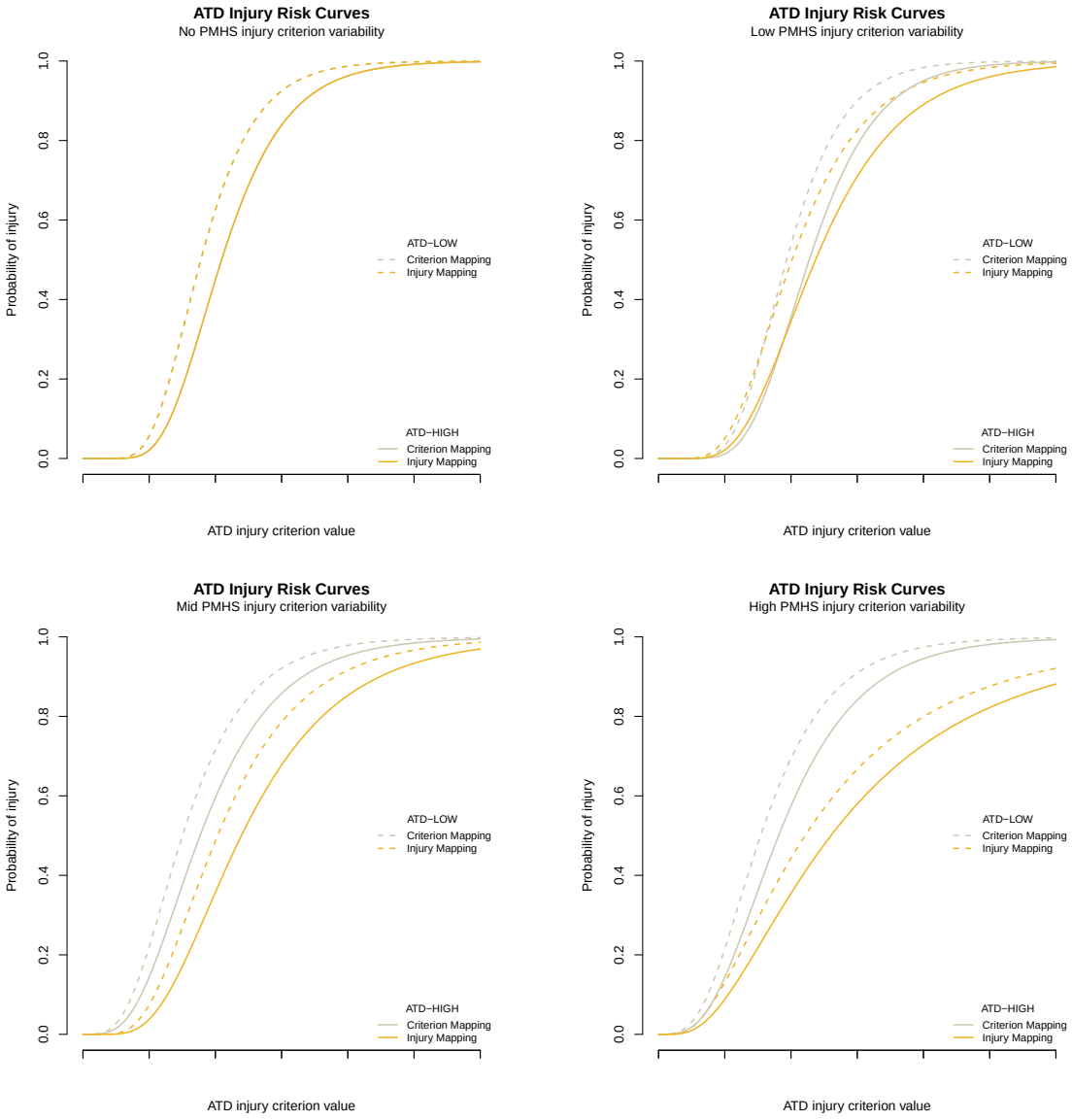

Figure 9: Comparison of injury risk curves based on ATD-LOW and ATD-HIGH injury criterion measurements. The injury risk curves are shown for different mapping methods and different variability of injury criterion values. All curves are based on one PMHS sample.

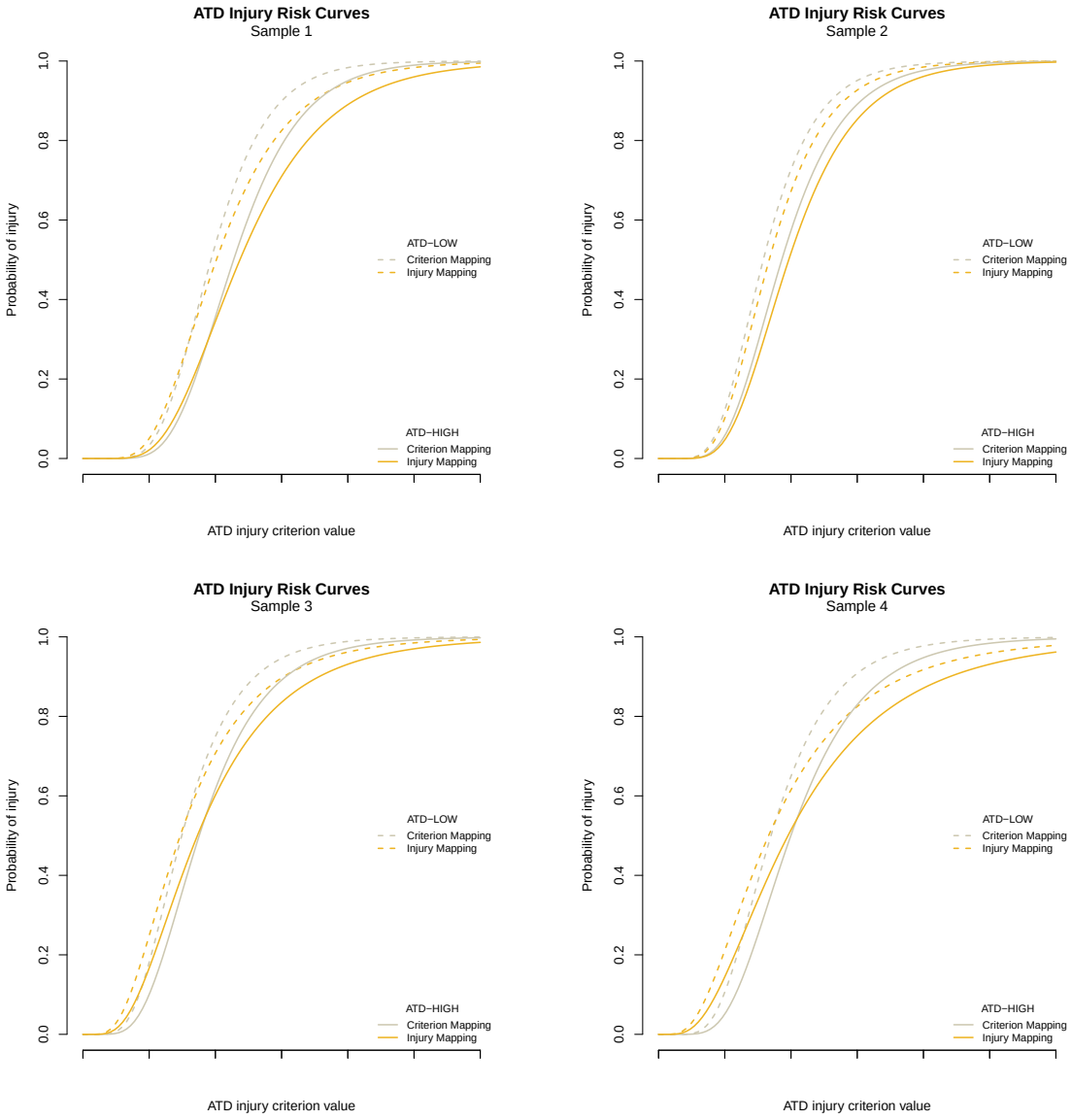

Figure 10: Comparison of injury risk curves based on ATD-LOW and ATD-HIGH injury criterion measurements. The injury risk curves are shown for different mapping methods and different PMHS samples. All curves are based on mid PMHS injury criterion variability.

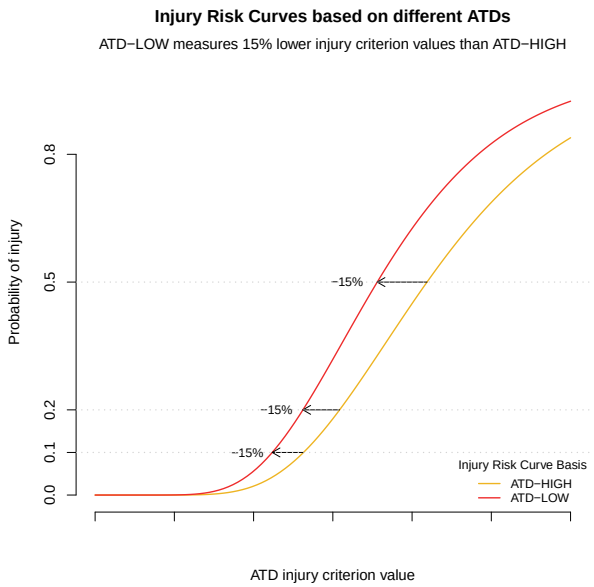

Figure 11: Shift of the ATD injury risk curve when built on basis of an ATD which measures 15% lower injury criterion values.

CONCLUSIONS

From the results of this study it can be concluded that a poor reproducibility of a specific ATD type will affect the resulting ATD injury risk curve which is in line with previous findings [4]. More precisely, an ATD injury risk function directly depends on the actual ATD which was used for the mapping of the ATD injury criterion values onto the PMHS test results. Different ATDs of specific type with poor reproducibility will lead to different injury risk functions. Characteristics of the PMHS sample, like the distribution of the biomechanical tolerance limit and the injury criterion variability in relation to a given load, do not change the effect of the poor reproducibility on the resulting injury risk curve. The same applies to the mapping method, it doesn't influence the effect of a poor reproducibility. Thus, a poor reproducibility can't be compensated by changing the biomechanical test data or the method of injury risk function development. The influence of a poor reproducibility on the ATD injury risk function can only be solved on the ATD side, not on the PMHS test side.

The main problem of a poor reproducibility of ATD injury criterion values is depicted in figure 12. If the injury risk curve was built with ATD-LOW but ATD-HIGH is used in a vehicle crash test then the calculated injury risks are higher than the biomechanical test data would actually indicate. Thus, the injury risk assessment is distorted and can lead to misleading conclusions about the safety rating of a vehicle. The extent of the distortion due to a poor reproducibility isn't known in reality. Solely because of the theoretical approach used in this study the distortion could be determined. In real vehicle crash tests, it is not known whether the ATD used corresponds to an ATD-LOW or an ATD-HIGH. Furthermore, it is not known how the ATD used in the crash test relates to the ATD used in the development of the injury risk function. The reason for this is not only that it is not known whether an ATD-LOW or an ATD-HIGH was used in the crash test, but also that it is not known which ATD was used in the development of the injury risk function. The certification of an ATD doesn't comprise such kind of information. Currently the implication of a poor ATD reproducibility on the safety rating of a vehicle is neither known nor addressed. To date no comprehensive knowledge about this potential problem is available and in-depth analyses of the implications of the ATD reproducibility are essential to understand the extent of the issue.

Due to the missing knowledge about the impact of the ATD reproducibility on injury risk functions only very general recommendations can be given to minimise a potential negative influence of a poor reproducibility on vehicle safety ratings. Selecting an injury criterion for a vehicle safety assessment not only its biomechanical performance needs to be considered but also its reproducibility with the utilised ATD. To reduce the probability of a significant distortion in the vehicle safety assessment as many ATDs as feasible should be used to determine the ATD injury risk

function. Another general approach to limit the extent of the problem is to use a ATD with mean injury criterion measurements within the whole population of ATDs of the same type. However, this approach requires a thorough assessment of the repeatability and reproducibility of the ATD type in question.

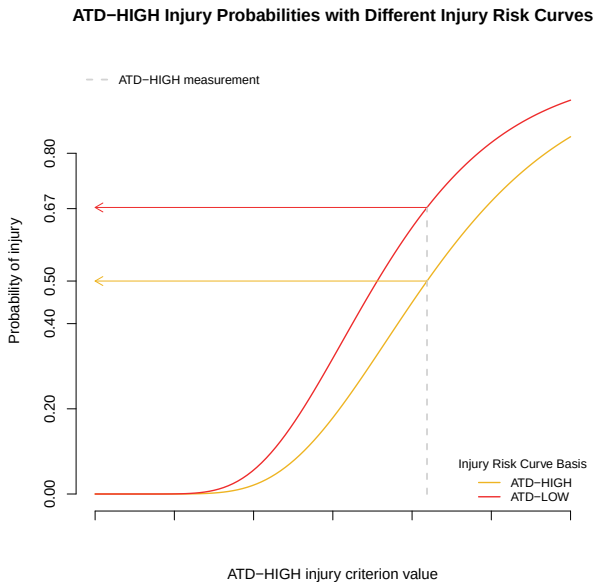

Figure 12: ATD-HIGH injury probabilities calculated with injury risk curves based on ATD-HIGH and ATD-LOW.

Limitations

This study has some limitations that need to be acknowledged. Firstly, no analytical universal prove is presented for the conclusions. All conclusions are based on theoretical simulation results based on artificial, albeit realistic, data. These data are dependent on specific assumptions which are non-verifiable. Secondly, only a theoretical and simple injury risk function was applied in the analyses and more complex injury risk functions with additional covariate may lead to diverging results. More complex injury criteria may also show diverging results. Thirdly, the repeatability of the ATDs wasn't considered. And last but not least only a low number of repeated ATD tests have been performed in the R&R study.

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APPENDIX

Table 2: PDB R&R data

dummy	test	rmax
dummyA	1	39
dummyA	2	40
dummyA	3	42
dummyB	1	40
dummyB	2	37
dummyB	3	41
dummyC	1	44
dummyC	2	46
dummyC	3	41
dummyC	4	41
dummyC	5	38
dummyC	6	42
dummyD	1	44
dummyD	2	42
dummyD	3	40
dummyE	1	42
dummyE	2	42
dummyE	3	44
dummyE	4	42
dummyE	5	39
dummyE	6	40
dummyF	1	45
dummyF	2	45
dummyF	4	43
dummyG	1	44
dummyG	2	37
dummyG	3	36
dummyG	6	40
dummyG	7	42

Table 3: Generated artificial current status biomechanical test data [load: load expressed as injury criterion values (= ATD measurement), btl: biomechanical tolerance limit, crit.pmhs: injury criterion value measured on the PMHS, cens: censoring status (0: right censored, 2: left censored)]

load	btl	crit.pmhs	cens
3773	2785	3538	2
3773	9194	4438	0
3773	2176	4276	2
3773	2421	4390	2
3773	4780	4695	0
3773	2786	4018	2
3773	1994	3559	2
3773	5402	3717	0

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load	btl	crit.pmhs	cens
3773	4997	3761	0
3773	2965	3865	2
2194	2958	2439	0
2194	3836	2535	0
2194	3660	2458	0
2194	3703	1752	0
2194	7779	1774	0
2194	1213	1576	2
2194	4308	1538	0
2194	5810	2342	0
2194	5658	1607	0
2194	1488	2289	2
3657	8581	3325	0
3657	2219	4438	2
3657	1973	5360	2
3657	1392	4268	2
3657	4630	2415	0
3657	4553	6870	2
3657	5438	4792	0
3657	3864	4002	2
3657	5442	3669	0
3657	3085	3215	2
3726	2384	2864	2
3726	5033	4681	0
3726	1880	3274	2
3726	7189	4768	0
3726	6472	3611	0
3726	4539	4972	2
3726	1861	3553	2
3726	7675	3446	0
3726	4574	4424	0
3726	2554	3804	2
5550	5520	6713	2
5550	2649	6407	2
5550	2306	6086	2
5550	2861	4341	2
5550	3813	5726	2
5550	2543	4498	2
5550	4461	4780	2
5550	4076	4940	2
5550	4131	5627	2
5550	4571	6105	2
3073	3296	2076	0
3073	9246	2156	0
3073	6468	4139	0
3073	4951	2533	0
3073	3570	2903	0
3073	4564	4840	2
3073	3300	4162	2
3073	3762	3170	0

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load	btl	crit.pmhs	cens
3073	3996	3643	0
3073	3853	3122	0
5125	6081	4988	0
5125	2307	6254	2
5125	8046	5383	0
5125	2785	5783	2
5125	6388	4784	0
5125	2409	5242	2
5125	4329	3434	0
5125	2236	6196	2
5125	3464	3924	2
5125	3339	6536	2
4955	3711	6752	2
4955	2646	6784	2
4955	6037	6091	2
4955	2465	4718	2
4955	4594	7429	2
4955	2904	3612	2
4955	8881	5543	0
4955	3534	7002	2
4955	3207	2851	0
4955	5852	3306	0