PERFORMANCE COMPARISON OF REAR IMPACT DUMMIES: Hybrid III (TRID), BioRID and RID2

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ABSTRACT

To access biomechanical neck loading associated with whiplash-associated injuries in low speed rear-end impact tests, three different types of dummies exist today, i.e. the conventional Hybrid III frontal impact dummy equipped with a special neck (TRID), the BioRID, and the RID2. The latter two are dummies specially designed for low severity rear-end impact. The objective of our study is to compare the performance of different seats using these three dummies in low speed rear-end impact sled tests. The dummy measurements are interpreted using the following performance criteria: NIC, neck moments and shear forces, N_{km} values, and the dummy rebound velocity. The NIC values produced by the HIII(TRID) are in general significantly lower compared to the BioRID and the RID2. Some seats however show lower NIC values with the BioRID than with the HIII(TRID), a phenomenon which can be explained with a particular design of the seat back.

The comparison between BioRID and RID2 shows comparable NIC values, whereas neck moments and forces tend to be higher with the RID2 but are in good correlation with the values measured for the BioRID. Both dummies show comparable rebound speeds. It is assumed that seat ratings performed using these two dummy types yield a similar ranking. Furthermore, it can also be expected that seat system optimisations performed using one dummy will also yield improved result when tested with the other one.

KEY WORDS: DUMMIES, HEAD RESTRAINT, NECK, REAR IMPACTS, SEATS

1. INTRODUCTION

A standard test procedure for accessing injury risk and seat performance in low speed rear end impact was developed during recent years /1/. Further elaboration resulted in the definition of the test conditions such as the crash pulse, seat adjustment, and measurement parameters, independent of the dummy type /2/. This procedure has been applied by using the three dummy types available today, i.e. the 50th percentile Hybrid III frontal impact dummy equipped with the special neck TRID, referred to in the following as HIII(TRID), the BioRID /3/ , and the RID2 /4/. The latter two are dummies specially designed for low severity rear end impact. Various authors have published studies comparing the HIII(TRID) and BioRID, resp. RID2 /5-8/, however information on test where various seat types have been tested using all three dummies under exactly identical test conditions is scarce. The objective of this study is to investigate possible differences in the assessment of the protection potential of seat systems when tested with different dummies. Results will benefit further evaluation of a standard test procedure as well as various efforts in improving the rear end impact performance of car seat systems.

Different criteria have been introduced: the neck injury criterion NIC /9/, N_{km} values /10,11/, and the dummy rebound velocity /12/. By the NIC criterion, the first phase of dummy movement in the rear impact, i.e. rearward translation of the head (s-shape), is assessed. NIC(t) reaches its maximum at the time when the head contacts the head rest. It is defined as:

$$NIC(t) = a_{rel}(t) \cdot 0.2 + (v_{rel}(t))^2,$$

with a_{rel} and v_{rel} being the relative acceleration and velocity between head and thorax. Neck forces and moments are traditional parameters for the rating of injury risk in frontal impacts. For rear end impacts, a combination of moment around the transverse axis and shear forces in the antero-posterior direction at the occipital condyle can be a potential criterion. Therefore, N_{km} has been proposed /9,10/. This criterion assesses mainly the second phase of the dummy movement, i.e. of the time interval with most rearward displacement. The N_{km} criterion is defined according to the following equation:

$$N_{km}(t) = F_x(t)/F_{int} + M_y(t)/M_{int}$$

where $F_x(t)$ and $M_y(t)$ are the shear force and the flexion/extension bending moment, respectively. Performing crash tests using a standard dummy, both values should be obtained from the load cell positioned at the upper neck. F_{int} and M_{int} represent critical intercept values used for normalization. Distinguishing positive shear, negative shear, flexion and extension, the N_{km} criterion identifies four different load cases: N_{fa} ,N_{ea} N_{fp} and N_{ep} . The first index represents the bending moment (f: flexion, e: extension) and the second indicates the direction of the shear force (a: anterior, i.e., in positive x-direction, p: posterior, i.e., in negative x-direction). The sign convention according to SAE J211/2 was used. Consequently, positive shear forces measured at the upper neck load cell indicate that the head is moved backwards relative to the uppermost cervical vertebra. The intersect-values for N_{km} are: M_y extension: 47.5 Nm, M_y Flexion: 88 Nm, shear force a and p: 845 N. The intersect values for all dummies were selected identically to enable a comparison. Future application of the N_{km} criterion will require the definition of different intersect values for each dummy type, as it is already common practice with the N_{ij} criterion, which is the basis of N_{km}. The rebound velocity was introduced to rate the energy absorption in the seat back and to evaluate the phase when the dummy is re-ejected from the seat. The rebound velocity is measured as the velocity of the upper thoracic vertebra T1 when passing in rebound its x-position before test. Other values added to the tables (upper neck moments and forces, head rebound velocity) are merely intended to help interpretation.

We started by comparing the HIII(TRID) with the BioRID using 13 different seat types. The selected seats cover a broad range of existing designs: seats with stiff and less stiff backrest were in the sample as well as seats with different neck protection systems, i.e. ‘active headrest’ and ‘yielding backrest’ systems. The seat types are referred to anonymously, i.e. identified with numbers only. After evaluation of this data, the 6 most representative seat designs were chosen to be tested with the RID 2. A summary of all test results can be found in the appendix.

Description	Seats
Conventional seat, actual design	2, 6, 7, 8, 10, 13
Conventional seat, older design (produced mid 1990^{th})	11, 12
Seat with neck protection system	1, 4, 9
Sports car seat	5
Bucket seat	3

Table 1: Description of the seats used for the comparison tests.

2. COMPARISON BioRID / HIII(TRID)

In the following we compare the results from one test pair HIII(TRID) and BioRID. The measurement values which showed an especially high discrepancy between the two dummy types are printed in bold. In general, the BioRID produces higher NIC-values than the HIII(TRID), cf. Table 2 and Fig. 1.

Both, shear forces and moments as well as the N_{km}-values derived thereof are significantly lower for the BioRID than for the HIII(TRID), cf. Table 3 and Fig. 2. This observation was confirmed except for seat 12. This outlier with an extension moment of 38.6 Nm for the BioRID collapsed in tests with both dummies. As this is a not desirable seat behaviour the results are not discussed further. In three tests with the BioRID, none of the four N_{km}-values showed a substantial magnitude, and in five tests with the BioRID neither a substantial moment nor a substancial shear force occurred. The rebound velocities measured for the BioRID tend to be higher than for the HIII(TRID), which is more clearly visible in the velocity of the head-centre of gravity than in the T1 velocity. This can be explained by the fact that the more compliant neck of the BioRID permits the head to swing forward in the rebound phase to a larger extent than the HIII(TRID). Generally, the rebound velocities between BioRID and HIII(TRID) are well correlated, cf. Fig. 3.

The tests with seat 3 forms the significant exception with respect to NIC. This seat has a relatively narrow backrest with distinctive but thin padded side supports. The Hybrid III-dummy is supported in this seat at the shoulders (rigidly connected to the spinal column) on the side faces so that the T1 acceleration is produced by this coupling and not by submerging the back into the upholstery. The BioRID moves its more compliant shoulders forward already when adopting the seated position and subsequently in the first phase of the test. Therefore the T1 acceleration is linked much less tightly to the sled acceleration, and consequently starts later: the result is a lower NIC value for the BioRID. In our opinion, the behaviour of the BioRID in this respect is more realistic than the behaviour of the HIII(TRID), i.e. the real ‘risk of injury’ during the first phase of movement would in practice be lower with this seat than as it would be expected on the basis of a HIII(TRID) test. There is a similar effect to a lesser extent with seat 5, but here, however, the NIC values do not diverge to the same extent. The test pair of seat 12 shows the relatively (- Factor 3) biggest difference in the NIC value. This type of seat almost collapsed with both dummy types. During the back repositioning process the TRID neck restricted the relative movement head-thorax even without head rest contact, because of its high stiffness, whereas the BioRID head could swing freely backwards. This can be understood by comparing the head accelerations. The same mechanism can also be observed with the tests of seat 11.

Another reason why the NIC values can turn out to be much higher with the BioRID than with the TRID is the way forces are introduced into the spinal column via the back rest. The thoracic spine of the Hybrid III dummy is made from a single, rigid piece of metal. A inhomogeneous stiffness distribution along the seat back, caused by e.g. the upper transverse support used in most seats, have less effect in this type of construction than in a vertebral column model built from an anatomically correct number of segments (i.e. 12 for the thoracic spine). In the event that the segment T1 or one of the adjacent segments impacts a rigid component of the seat back, high acceleration peaks can occur in the affected segment or its neighbour, because the coupled mass of the vertebral column is lower than with a single, rigid steel block. This is e.g. the reason for the large difference in the NIC values for seat 2 (13.0/24.0, both at t=80 ms).

Discussion of the comparison HIII(TRID)/BioRID. Certainly, comparisons between the dummies based on the available test results are meaningful: however, it should be noted that the two dummies are, in mechanical terms, two totally different systems already by design. Whereas the TRID neck merely represents a supplement to the Hybrid III dummy, designed to overcome the worst inaccuracies of the original Hybrid III neck, the BioRID is a entirely new design with regard to the thorax as well as the neck . The number of mechanical degrees of freedom, i.e. joints, is drastically increased in comparison with the Hybrid III, and the joints are in line with human anatomy. Such a design does not only result in reduced ‘rigidity’ of the vertebral column, but also the stiffness gradients in the function of the extension/flexion angle or the retraction distance are characteristically different. This results in the head acceleration of the BioRID (in contrast to the HIII(TRID), cf. Fig. 4) being practically zero before the head restraint contact (assuming a head restraint is present and positioned in a ‘reasonable’ way). Therefore, a higher relative velocity and relative acceleration can be built up than for the TRID, resulting in higher NIC values. Because the relative velocity appears as a squared term in the NIC formula, and the relative acceleration as linear term, however, the relations between NIC with HIII(TRID) and NIC with BioRID cannot accordingly be characterised e.g. by a constant factor.

The HIII(TRID) shows generally higher extension moments than the BioRID. This might lead to the assumption that the first shows greater sensitivity of moment response than the latter. It has to be taken into account, however, that the highest extension moments are obtained around the maximum rearward displacement of the dummy. At this point in time the biggest difference in the kinematics of the two dummies occurs. Due to the more compliant neck, the head of the BioRID is displaced more rearwards in respect to the thorax than the HIII(TRID) head, which, however, shows a greater rotation than the first. The greater rotation gives rise to higher neck moments, whereas the more parallel rearward movement of the BioRID head allows the head to be supported better by the head rest.

In our view the test series showed that the results obtained with the HIII(TRID) may be transferred to the BioRID and vice versa only with precise knowledge of details and even then, with considerable uncertainties. Therefore, in a test specification it cannot be left open which dummy is used. As the BioRID dummy simulates the actual biomechanical conditions of people better than the HIII(TRID), the following comparison with the RID2 shall basically refer to the BioRID.

Seat	Code*)	NIC	[m^2/s^2]
		TRID	BioRID
1	XA/XB	8,5	9,0
2	AB/BN	13,0	24,0
3	AC/BA	***23,2***	***15,2***
4	AF/BD	14,0	15,3
5	AI/BH	31,2	27,7
6	AO/BB	23,9	19,9
7	AQ/BG	18,7	26,9
8	XC/XD	18,4	26,0
9	BK/BC	14,1	19,2
10	AM/XE	15,6	24,4
11	BM/BE	13,0	22,8
12	BL/BF	**11,1**	**33,4**
13	BJ/BI	7,3**)	20,5

Table 2: NIC-values for different seat designs
*) Code refers to earlier publications /1/.
**) Head rest put into the most forward position

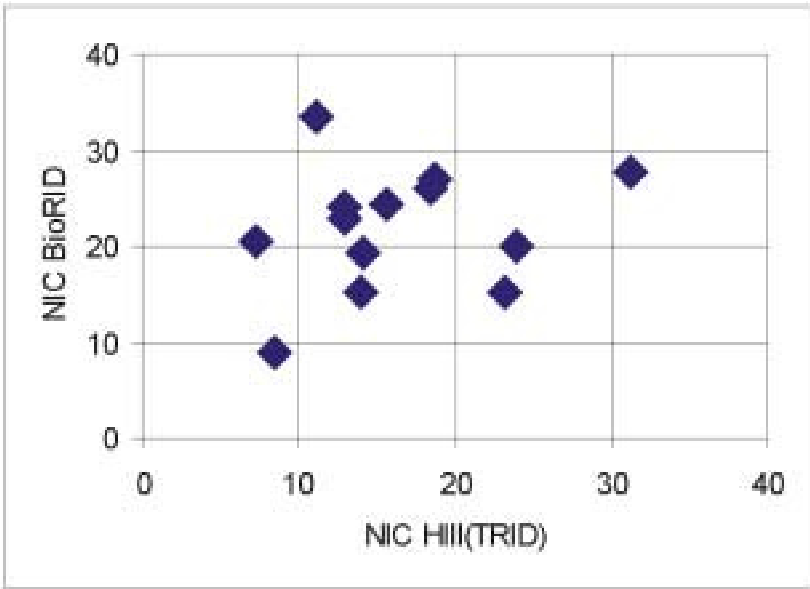

Fig. 1: Comparison of NIC of tests with BioRID and HII(TRID)

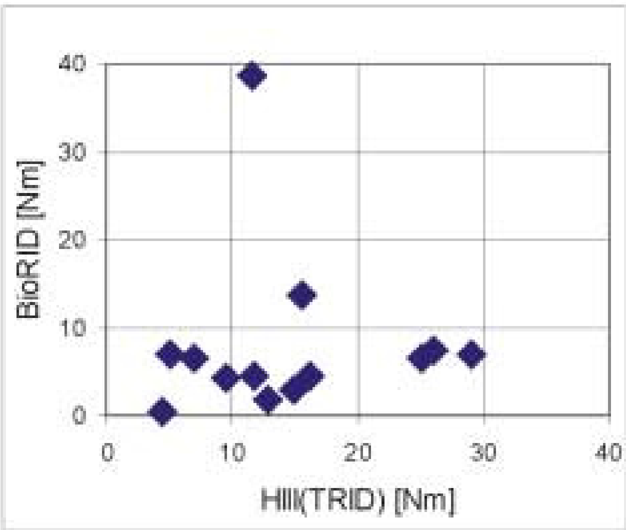

Fig. 2: Comparison of neck moments in extension of tests with BioRID and HIII(TRID)

Seat	N_{ep}		N_{fa}		N_{ea}		N_{fp}	
	TRID	BioRID	TRID	BioRID	TRID	BioRID	TRID	BioRID
1	0.36	0.04	0.13	0.01	0.24	0.00	0.03	0.00
2	0.07	0.01	0.54	0.18	0.19	0.00	0.00	0.05
3	0.31	0.12	***0.90***	***0.00***	0.16	0.00	0.20	0.13
4	0.16	0.16	0.56	0.38	0.03	0.06	0.14	0.16
5	0.43	0.09	0.48	0.14	0.13	0.09	0.12	0.15
6	0.35	0.07	0.66	0.34	0.27	0.06	0.19	0.05
7	0.66	0.17	0.43	0.27	0.36	0.15	0.24	0.07
8	**0.69**	**0.06**	0.31	0.14	0.49	0.04	***0.43***	***0.03***
9	0.09	0.08	0.40	0.37	0.28	0.09	0.19	0.07
10	0.09	0.03	0.40	0.03	0.41	0.43	0.20	0.07
11	0.06	0.05	0.33	0.11	0.75	0.22	0.24	0.05
12	0.00	0.08	0.09	0.00	**0.46**	**1.13**	0.09	0.04
13	0.09	0.15	0.38	0.49	0.26	0.06	0.09	0.06

Table 3: N_{km} values for different seat designs, the resp. max. values are given in bold

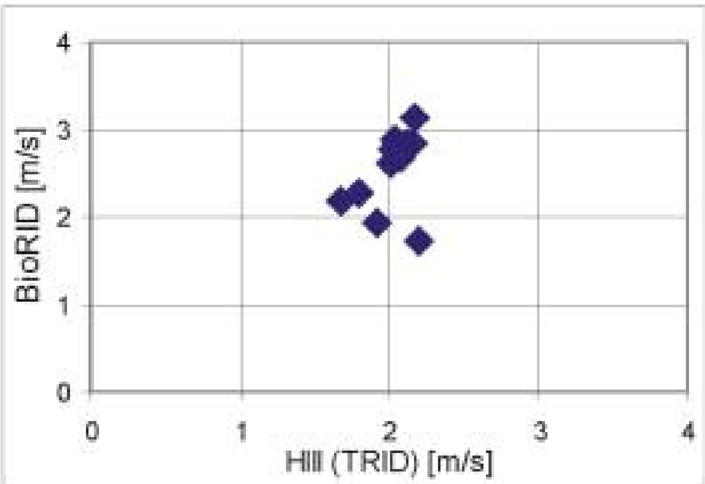

Fig. 3: Comparison of rebound speeds at T1 level

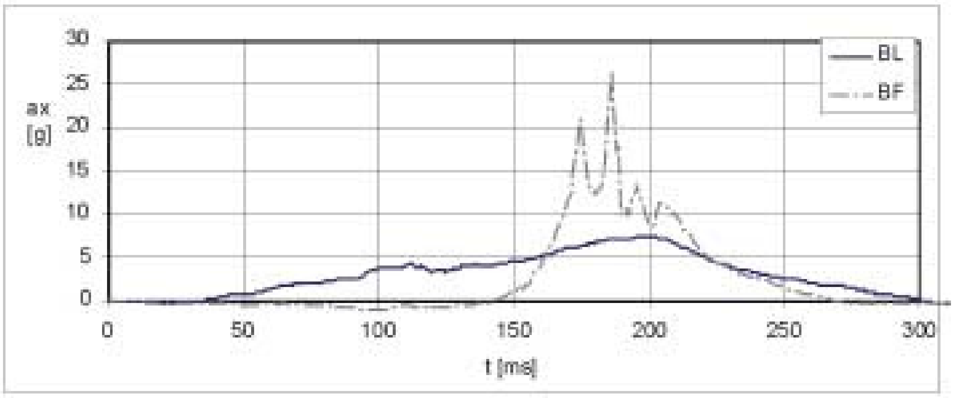

Fig. 4: Head acceleration of seat 12 tests, BL: HIII(TRID), BF: BioRID

3. COMPARISON BioRID / RID2

The design principles of the BioRID and the RID2 are presented in /3/ and /4/, respectively. The most significant difference between the two dummies, apart from the slightly lower sitting height of the RID2, is the design of the thoracic and lumbar spine. The spine of the BioRID is based on individual vertebrae identical in numbers and geometry to the human spine, whereas the spine of the RID2 consists of two rigid metal parts connected by a rubber block with a back pad to improve seat interaction. Another difference can be found in the design of the shoulders and their connection to the spine. The RID2 shows very compliant shoulders when only one shoulder is moved forward or backward, but stiffer shoulders when both shoulders are moved forward simultaneously, as it happens in a rear end impact, i.e. the shoulder movement is mechanically coupled such that, if one shoulder is moved backwards, the other moves forward. In contrast to this, the BioRID shoulders move independently from each other.

For the comparison RID2 / BioRID, four seat types were selected which had shown most striking features in the previous comparison of BioRID with the HIII(TRID), i.e. seats: 2, 3, 7, and 11. In addition, two seats featuring a neck protection system (seats 1 and 4) were selected. The results have been evaluated in a similar way as described before. The intersect-values for the N_{km}-calculation for the RID2 dummy were again chosen identical to the previous tests.

Table 4 and Fig. 5 show a comparison of NIC values. At the lower end, RID 2 produces slightly higher NIC values, on the upper end slightly lower values, but the ‘ranking’ of seats remains nearly the same. Only seats 3 and 4 change places. As the four NIC values are very close together (i.e. from 15.0 to 15.8), this is to our experience well within the standard deviation of test results. Generally, the correlation is very good and linear. Table 5 and Fig. 6 show neck moments and shear forces (N_{km}). In all four parameters, RID 2 produces significantly higher values. The mean values were calculated. These are approximately 30 % higher for the moments but can deviate up to a factor of 5 for shear forces. However, a good correlation can be seen for shear forces and flexion. As the factors N_{km} is deduced from are different, these values are not comparable, cf. Table 6. A good correlation can again be found in T1 rebound velocity, which tends to be slightly higher for the BioRID, cf. Fig. 7.

Seat	Code	NIC [m2/s2]	
		BioRID	RID2
1	XB/DC	9.0	12.2
2	BN/DB	24.0	19.1
3	BA/DA	15.2	15.8
4	BD/DF	15.3	15.0
7	BG/DE	26.9	20.9
11	BE/DD	22.8	18.4

Table 4: BioRID/ RID 2 comparison, NIC-values for different seat designs

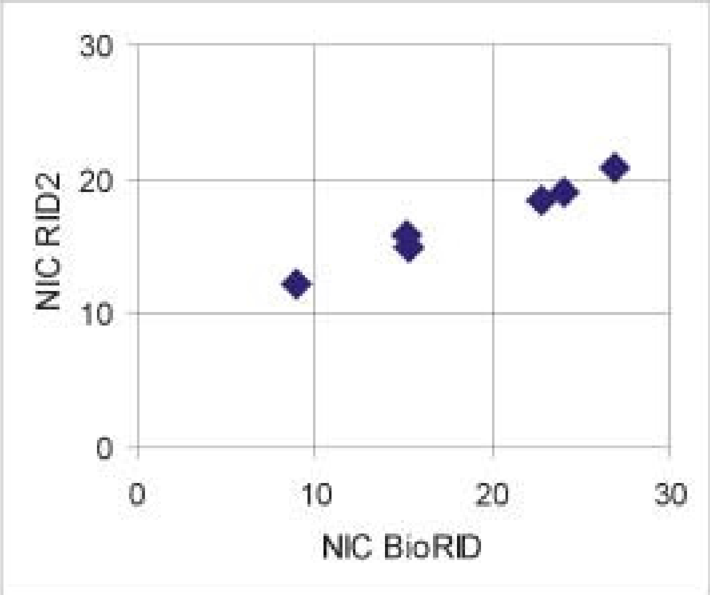

Fig. 5: Comparison of NIC of tests with BioRID and RID2

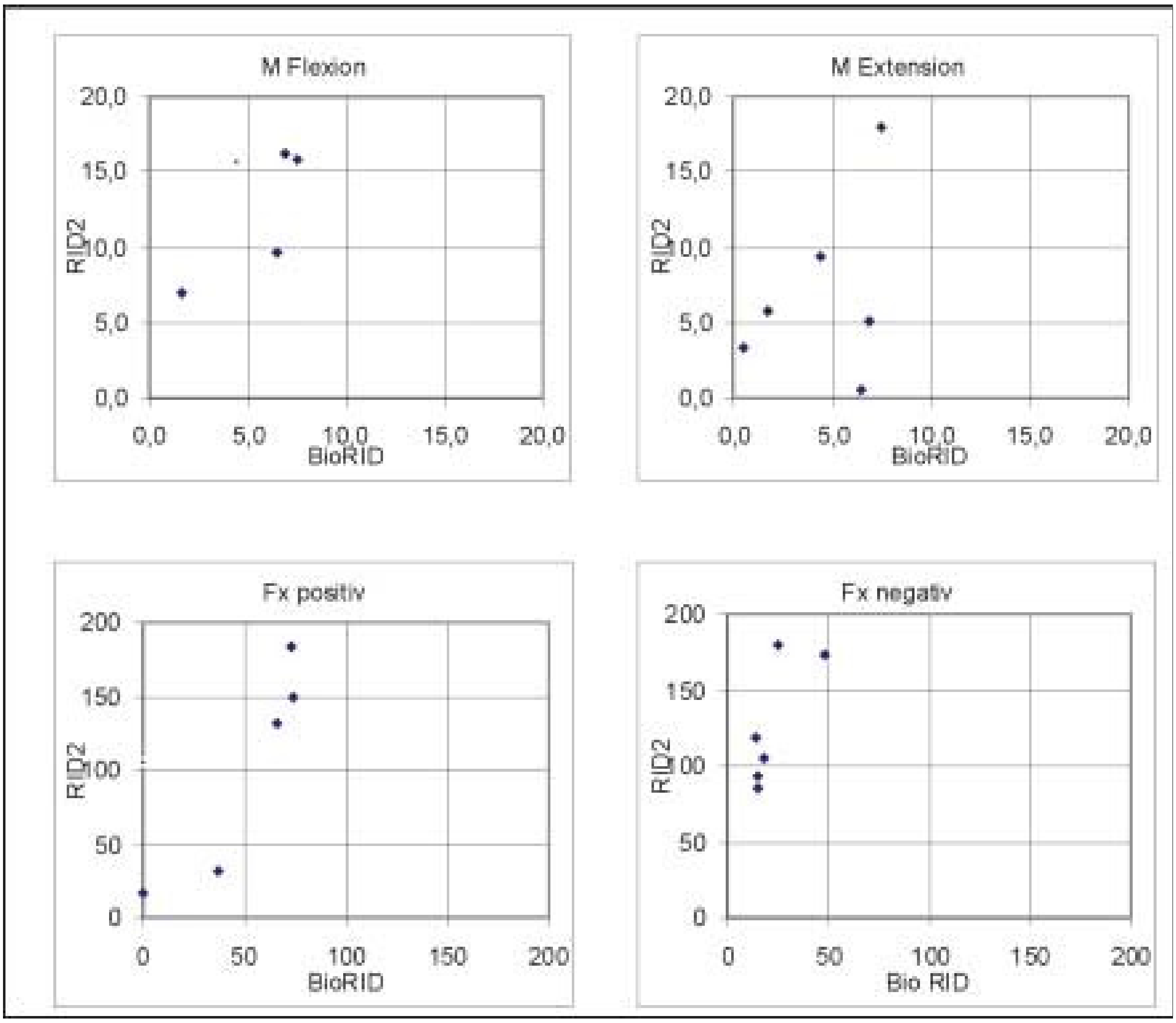

Fig. 6: Comparison of Neck Moments and Forces BioRID and RID2

Seat	M extension [Nm]		M flexion [Nm]		Fx positiv [N]		Fx negativ [N]	
	BioRID	RID2	BioRID	RID2	BioRID	RID2	BioRID	RID2
1	1.7	5.8	1.0	7.0	0	17	18	106
2	0.5	3.3	9.6	21.8	73	184	15	86
3	4.4	9.4	6.9	15.7	0	105	48	173
4	6.9	5.1	30.3	16.3	37	32	14	119
7	7.5	18.0	18.0	15.8	66	132	25	180
11	6.5	0.5	4.3	9.6	74	149	15	94
mean	4.6	7.0	11.7	14.4	41.7	103.1	22.5	126.3

Table 5: BioRID/ RID 2 comparison, Lower Neck Moments and Forces

Seat	Nep		Nfa		Nea		Nfp	
	BioRID	RID2	BioRID	RID2	BioRID	RID2	BioRID	RID2
1	0.04	0.24	0.01	0.10	0.00	0.03	0.00	0.11
2	0.01	0.17	0.18	0.46	0.00	0.00	0.05	0.16
3	0.12	0.22	0.00	0.12	0.00	0.00	0.13	0.00
4	0.16	0.18	0.38	0.22	0.06	0.00	0.16	0.26
7	0.17	0.59	0.27	0.28	0.15	0.00	0.07	0.16
11	0.05	0.04	0.11	0.29	0.22	0.00	0.05	0.14

Table 6: BioRID / RID 2 comparison, N_{km} values for different seat designs

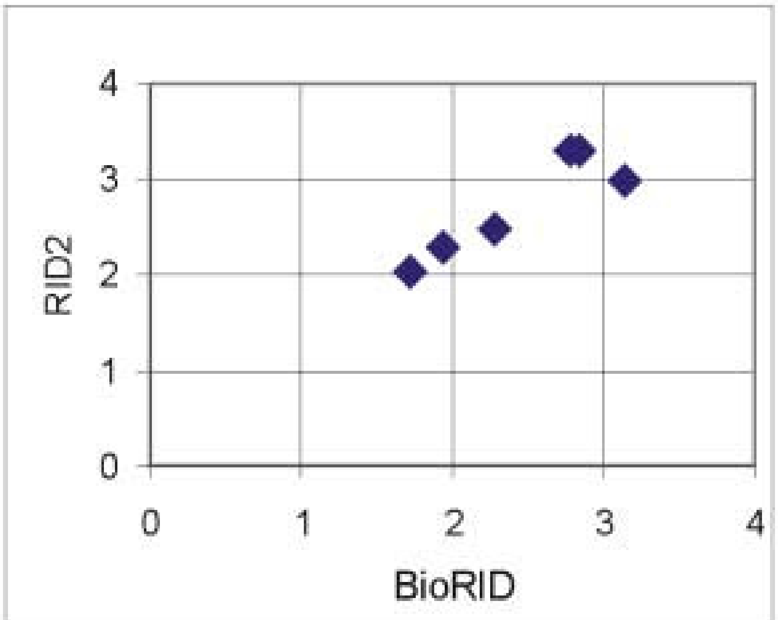

Fig. 7: BioRID/ RID 2 comparison, rebound speeds at T1 level

Discussion of the comparison BioRID/RID2. It has to be pointed out, that the measured parameters with the RID2 show no artefacts which would have to be explained by a special seat design as observed with the HIII(TRID). This is of special importance as the RID2 exhibits a stiffer thorax than the BioRID. Seats 2 and 3, which showed high deviations in the HIII(TRID) tests due to ‘special back rest’ reasons, show comparable results now in the BioRID and RID2 comparison.

Seat 3 is difficult to compare. This seat exhibits a fixed head restraint with a hole in its centre. The head of the BioRID contacted the upper rim of this head restraint, while the head of the RID 2 entered exactly into the hole. Both tests show almost identical NIC values due to the fact that the RID 2 was positioned in a way that led to a head-head restraint distance almost half that of the BioRID test[1]. Thus the effect of both the (not recommended) hole in the head restraint and the stiffer shoulders of the RID2 were compensated.

4. DISCUSSION

The comparison between HIII(TRID) and BioRID yielded different values which did not even correlate for all parameters under investigation, i.e., NIC, neck moments and forces, N_{km} and rebound velocity. We recommend not to use the HIII(TRID) further for low speed rear impact testing as it clearly deviates in kinematics from the two new dummies which have been developed to show more realistic human behaviour in such rear impacts. BioRID and RID 2 show comparable results in NIC and rebound velocity, but different values in neck moments and shear forces. However, a correlation in flexion and forces can be seen. As a result, the N_{km} values, which are deduced from forces and moments, deviate. A satisfactory explanation for the different behaviour cannot be deduced from our tests. It is proposed to study this in a generic test environment which allows to adjust stiffness and position of back rest and head rest. In future, it will be necessary to determine the intersect-values for each dummy separately, in the same way that this is done for the N_{ij} criterion.

It has been proposed /13/ to use the displacement of the OC joint in a co-ordinate system fixed to T1 in order to generate a new performance criterion, termed NDC (neck displacement criterion). We have generated such displacement plots from film analysis for the BioRID and the RID2 tests. It is important that the rotation of the T1 co-ordinate system is taken into account when generating NDC plots. Since there was no ‘T1 locator’ on the Hybrid III dummy in our tests, the corresponding plots for the HIII(TRID) tests could not be generated. An example of a plot of the rearward displacement of the OC joint (along the x-axis of a co-ordinate system fixed to and rotating with T1) against the relative rotation between T1 and the head is shown in Figure 8. The graph at the top of the figure show the plot for the RID2, the BioRID plot is shown below[2]. The best correlation between the two dummies is seen in seat 11, cf. Fig. 8. This is a 'standard' seat, and it is the only seat which produced significant extension angles together with significant rearward translations with both dummies. The plots of the other tests bear less similarity to each other. Interpretation is difficult, since there is still a lack of experience with the NDC method.

The only conclusion we can make from the NDC plots is that, although the two dummies show comparable values for e.g. NIC and other criteria, they produce these measurement values with a significantly different kinematic behaviour. This can be explained through the different mechanical design of the two dummies. Further research is needed in order to determine whether one or the other design more closely resembles the 'human' behaviour. Also, the influence of the different sitting height of the two dummies needs close examination from a kinematic standpoint.

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[1] The seating procedures for both dummies are still much-discussed subjects

[2] Due to the sign convention introduced by Viano /13/, rearward translation of OC vs. T1 shows up on the positive x-axis of the graphs, and a rearward rotation (extension) of OC vs. T1 on the positive y-axis.

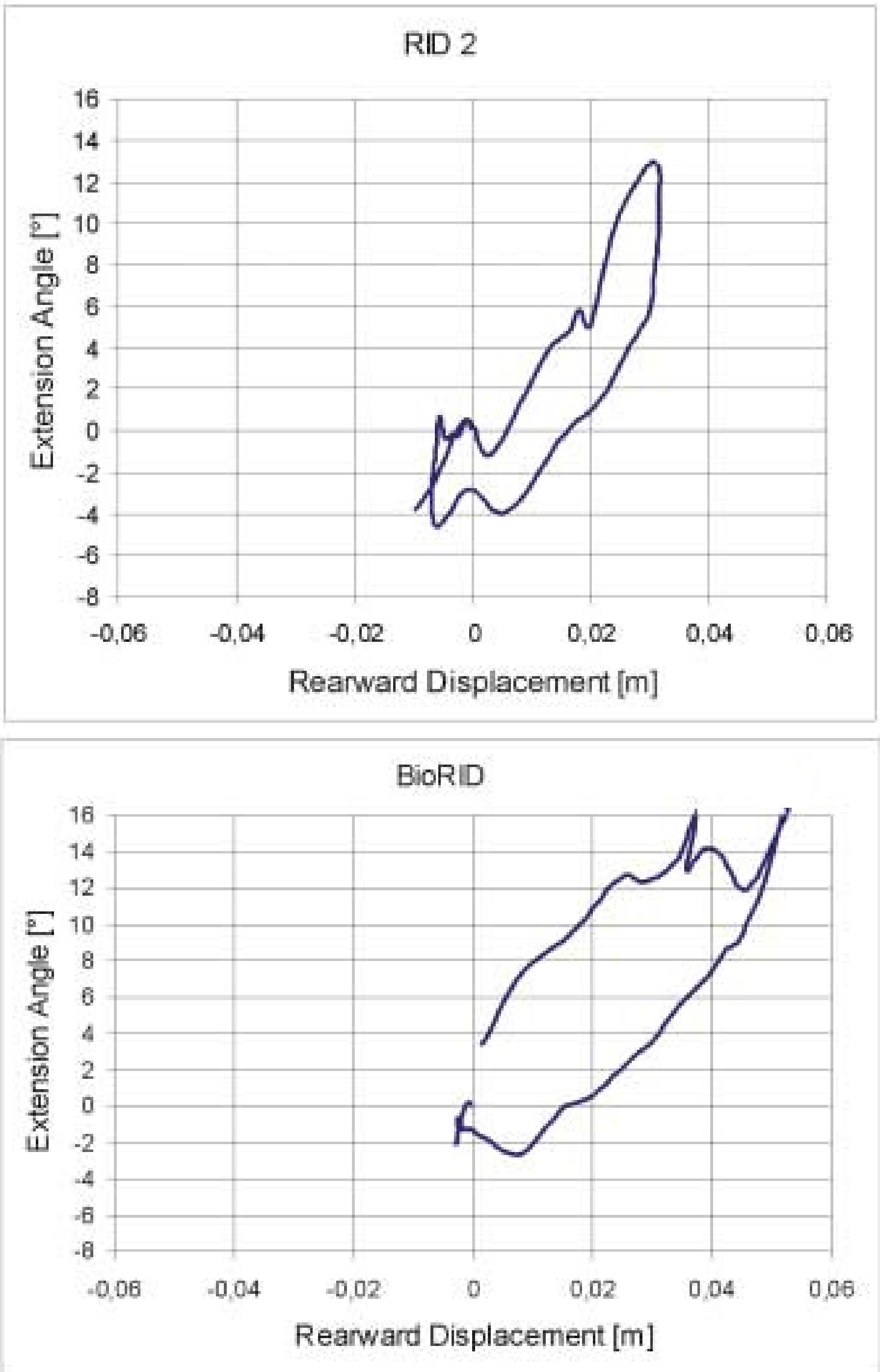

Fig. 8: NDC plot for seat 11

It is obvious that a test procedure for low speed rear end impact must define the dummy which has to be used. From our series of 6 comparison tests between RID2 and BioRID, no recommendation as to which dummy should be preferred can be made. In fact, in future research it might well be found that both dummies could be specified as an alternative in a test procedure, and that only the results (i.e. tolerance limits) should be interpreted in a slightly different way. We have found little evidence that improvements to seat designs made using one of the two dummies would turn out contrary results when tested with the other one. Furthermore, our experience so far indicates that both dummies seems to 'rate' the seats under investigation in a similar way.

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APPENDIX: SUMMARY OF ALL TEST RESULTS

BioRID /TRID/ RID2 Comparison Tests			Dist.	NIC		My				Fx				Nkm								Elasticity			
			d_{hor}	NIC_{max}	t	ext.	t	flex.	t	max a	t	max p	t	Nep	t	Nfa	t	Nea	t	Nfp	t	v_{Head}	t	v_{T1}	t
Seat	Code	Dummy	mm	m^2/s^2	ms	Nm	ms	Nm	ms	N	ms	N	ms		ms		ms		ms		ms	m/s	ms	m/s	ms
1	XA	TRID	50	8,5	55	12,8	140	5,3	56	109,0	94	86,0	144	0,36	141	0,13	62	0,24	120	0,03	50	3,00	190	2,20	166
	XB	BioRID	35	9,0	62	1,7	116	1,0	99	0,0	0	18,0	140	0,04	116	0,01	99	0,00	0	0,00	0	2,36	313	1,72	301
	DC	RID 2	50	12,2	71	5,8	131	7,0	88	16,7	91	105,5	152	0,24	113	0,10	91	0,03	287	0,11	161	2,10	307	2,02	296
2	AB	TRID	70	13,0	83	4,5	144	17,7	116	285,0	116	40,6	169	0,07	178	0,54	116	0,19	94	0,00	0	3,52	192	2,18	169
	BN	BioRID	70	24,0	80	0,5	64	9,6	113	73,0	120	14,8	201	0,01	67	0,18	117	0,00	0	0,05	196	4,63	201	3,14	201
	DB	RID 2	80	19,1	85	3,3	187	21,8	116	184,0	113	86,0	194	0,17	191	0,46	113	0,0	0	0,16	135	3,85	207	3,00	219
3	AC	TRID	100	23,2	78	11,8	119	35,9	102	418,0	102	96,1	168	0,31	119	0,90	102	0,16	115	0,20	168	3,00	162	1,80	168
	BA	BioRID	90	15,2	78	4,4	134	6,9	103	0,0	0	48,0	99	0,12	135	0,00	0	0,00	0	0,13	105	2,98	181	2,27	178
	DA	RID 2	50	15,8	117	9,4	185	15,7	84	105,0	79	173,0	105	0,22	104	0,12	79	0,00	0	0,00	0	2,69	178	2,49	168
4	AF	TRID	85	14,0	74	5,1	151	23,0	115	251,0	114	74,0	195	0,16	152	0,56	114	0,03	142	0,14	195	2,94	195	2,12	195
	BD	BioRID	75	15,3	69	6,9	174	30,3	112	37,0	108	14,4	187	0,16	175	0,38	112	0,06	157	0,16	125	4,05	187	2,84	187
	DF	RID 2	75	15,0	73	5,1	191	16,3	114	32,0	108	119,0	140	0,18	192	0,22	109	0,00	0	0,26	126	3,77	194	3,31	197
5	AI	TRID	90	31,2	81	16,2	117	18,7	101	229,0	101	64,3	165	0,43	118	0,48	101	0,13	111	0,12	165	3,27	167	2,08	165
	BH	BioRID	100	27,7	74	4,4	160	11,6	108	29,0	101	33,0	114	0,09	161	0,14	103	0,09	160	0,15	111	3,86	178	2,68	171
		RID 2	not tested with RID2																						
6	AO	TRID	110	23,9	98	14,9	143	22,0	121	348,0	120	77,0	210	0,35	143	0,66	121	0,27	139	0,19	219	2,69	217	2,02	219
	BB	BioRID	80	19,9	97	3,0	195	22,7	123	81,0	118	0,0	215	0,07	195	0,34	122	0,06	102	0,05	71	3,95	218	2,62	215
		RID 2	not tested with RID2																						
7	AQ	TRID	35	18,7	92	26,0	139	8,5	160	287,0	115	114,0	182	0,66	140	0,43	115	0,36	131	0,24	182	3,50	184	2,03	182
	BG	BioRID	40	26,9	75	7,5	102	18,0	121	66,0	115	25,3	178	0,17	102	0,27	120	0,15	104	0,07	73	4,86	181	2,77	178
	DE	RID 2	45	20,9	95	18,0	172	15,8	128	132,0	116	180,0	172	0,59	172	0,28	126	0,00	0,	0,16	134	3,93	203	2,29	204
8	XC	TRID	35	18,4	102	29,0	155	15,2	248	257,0	125	222,0	235	0,69	154	0,31	124	0,49	147	0,43	243	3,21	209	2,06	208
	XD	BioRID	50	26,0	96	6,9	210	6,7	123	55,0	126	12,6	180	0,06	180	0,14	123	0,04	155	0,03	110	4,48	200	2,83	180
		RID 2	not tested with RID2																						
9	BK	TRID	115	14,1	69	9,6	138	8,9	204	257,0	105	90,0	197	0,09	164	0,40	104	0,28	135	0,19	204	2,57	194	1,68	204
	BC	BioRID	110	19,2	72	4,3	173	25,4	116	78,0	111	15,9	207	0,08	178	0,37	113	0,09	173	0,07	68	3,42	209	2,19	207
		RID 2	not tested with RID2																						
10	BM	TRID	105	15,6	104	25,0	155	7,4	223	319,0	137	101,0	223	0,09	193	0,40	138	0,41	131	0,20	223	3,25	222	2,04	223
	XE	BioRID	110	24,4	94	13,6	127	3,4	203	124,0	123	28,0	204	0,03	221	0,03	110	0,43	127	0,07	205	4,72	221	2,88	221
		RID 2	not tested with RID2																						
11	BM	TRID	60	13,0	105	25,0	148	14,9	250	277,0	122	121,0	238	0,06	209	0,33	122	0,75	148	0,24	235	2,76	248	1,92	250
	BE	BioRID	55	22,8	76	6,5	128	4,3	60	74,0	132	14,6	222	0,05	208	0,11	137	0,22	130	0,05	59	3,40	235	1,93	222
	DD	RID 2	55	18,4	77	0,5	36	9,6	96	149,0	97	94,0	227	0,04	147	0,29	97	0,0	0	0,14	244	2,54	243	2,28	244
12	BL	TRID	60	11,1	109	11,6	206	4,4	327	210,0	185	32,0	322	0,00	0	0,09	68	0,46	198	0,09	327	seat collapsed, no rebound speed to determine			
	BF	BioRID	60	33,4	146	38,6	187	2,1	134	291,0	186	13,0	94	0,08	252	0,00	144	1,13	187	0,04	133				
		RID 2	not tested with RID2																						
13	BJ	TRID	30	7,3	57	7,0	89	13,9	117	210,0	107	72,6	211	0,09	209	0,38	114	0,26	88	0,09	211	3,34	204	2,16	211
	BI	BioRID	40	20,5	84	6,5	184	35,3	125	93,0	121	15,8	202	0,15	184	0,49	121	0,06	175	0,06	85	4,07	202	2,84	202
		RID 2	not tested with RID2																						