PROTECTION OF OVERWEIGHT CHILDREN IN CHILD RESTRAINT SYSTEMS

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Paper Number 09-0414

ABSTRACT

According to the German road traffic regulations children up to the age of 12 or a body height below 150 cm have to use approved and appropriate child restraint systems (CRS). CRS must be approved according to UN-ECE Regulation No. 44. The regulation classifies CRS in 5 body weight categories. The upper weight group is approved for children from 22 to 36 kg.
However, studies show that already today many children weigh more than 36 kg although they have not reached a size of 150 cm. Therefore, no ECE R44 approved CRS is available for these "overweight" children. In conclusion, today's sizes and weights of children are no longer represented by the current version of the ECE R44. The heaviest used dummy (P10) weighs just 32.6 kg and has a body height of 137.9 cm. Statistical data of German children show that already 5% of the children at a size of 137.9 cm have a body weight above 45.3 kg. Regarding children at a body height of 145 cm, the 95th percentile limit is at a weight of 53.3 kg. Based on these data 4 dummies with different heights and weights were defined and produced. Two of them are "overweight".
Up to now, there is no experience how current child restraint systems perform in a car crash if they are used by children with a body weight above 36 kg and a size smaller than 150 cm.
In the future, different child restraint systems will be tested with respect to the ECE R44 regulation using these "overweight" dummies.

INTRODUCTION

Today, child restraint systems are very popular. Investigations show that in 2007 97% of all children transported on German roads were restrained with child restraint systems [1]. Compared to 1992, the restraint rate increased by 25%. During the same period the number of seriously and fatally injured children decreased significantly. Nevertheless, the number of children restrained improperly, the so called "misuse", is still very high.

Figure 1. 10 year old boy (body size 144.2 cm, body weight 41.6 kg) in an Opel Astra (model year 2003) without child restraint system. Arrows indicate critical positions of the safety belt.

This paper deals with another problem. In Germany it is mandatory that children younger than 12 or smaller than 150 cm have to use child restraint systems. The size limit results from the fact that the standard safety belts in the cars do not fit with smaller children. The shoulder belt touches the neck and the lap belt slips from the pelvis into the abdominal region as shown in figure 1.

Using booster seats – which must be approved according to UN-ECE Regulation No. 44 – the position of children in the seat rises and belt rooting is improved. Figure 2 shows the boy from figure 1 using such a child restraint system.

Figure 2. 10 year old boy (body size 144.2 cm, body weight 41.6 kg) in an Opel Astra (model year 2003) with child restraint system.

The shoulder belt no longer touches the neck of the boy.
Unfortunately, the type approval of child restraint systems is limited to a maximum body weight of 36 kg so that the boy from figure 1 and 2 (body weight 41.6 kg) has to use booster seats which are not certified for his weight. This is not a particular case as shown in this paper and the crash performance of child restraint systems in such *overload* cases is completely unknown. Therefore, the German Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt) initiated a project to investigate this problem. First results are presented in this paper.

Detailed results from anthropometric measurements, which are presented in the next chapter, clearly indicate that a lot of children who are shorter than 150 cm weigh more than 36 kg. Based on these data sizes and weights for new child dummies are defined. As it is impossible to develop a completely new child dummy a P10 dummy was modified. The exact definition of the modified P10 dummies and the manufacture process is described in the following chapters.

ANTROPOMETRIC DATA

Former publications [2] made evident that the median weight of children at the size of 150 cm is much higher than the 36 kg limit defined in UN-ECE Regulation No. 44. Actual data corroborate this statement. The data presented below was collected by the University of Jena in cooperation with CrescNet. Table 1 and table 2 show the weight and size of 34272 German children (girls and boys). Even the 50% percentile weight of the 11 years old children is above 36 kg. The average size of these children is 147.6 cm. An exact correlation between weight and size cannot be inferred from table 1 and 2.

Table 1.
Body weight in kg of German children for three different percentiles. The second column shows the number of measured children. [database CrestNet 2006-2008]

age [years]	N	body weight [kg]		
		5%	50%	95%
6	6703	17.3	21.6	29.7
7	5908	19.2	24.4	34.9
8	5349	21.1	27.6	40.8
9	4925	23.3	31.2	47.2
10	4288	25.7	35.2	54.1
11	3767	28.5	39.6	61.2
12	3332	31.7	44.4	68.5

Table 2.
Body size in cm of German children for three different percentiles. The second column shows the number of measured children. [database CrestNet 2006-2008]

age [years]	N	body size [cm]		
		5%	50%	95%
6	6703	109.5	117.9	126.6
7	5908	115.1	124.1	133.7
8	5349	120.4	130.2	140.5
9	4925	125.5	136.1	147.0
10	4288	130.6	141.9	153.4
11	3767	135.7	147.6	159.7
12	3332	140.8	153.3	166.0

Therefore, the data were analyzed for three different size classes. These classes are defined as follows; from 134 cm to 136 cm, from 144 cm to 146 cm and from 149 cm to 151 cm. Choosing a range of 2 cm, enough children can be evaluated. Exact data are listed in table 3 to 5. Due to the fact that not all dimensions were evaluated for all children the number of measured children differs. Table 3 points out that at least 5 % of all children in the size range 134 cm to 136 cm are heavier than 36 kg. The data in table 4 is more critical. The medium weight reaches the weight level of 37.5 kg. 5 % of all the children in the size range of 144 cm to 146 cm weigh more than 53.3 kg. Table 5 shows a similar distribution. All data indicate that the European regulation No. 44 no longer represents current children living in Germany. Based on these data new overweight dummies were defined and manufactured.

Table 3.
Different anthropometric data of German children with a body size of 134-136 cm. The second column shows the number of measured children. [database CrestNet 2006-2008]

Children body size 134-136 cm	N	percentile		
		5%	50%	95%
Age [years]	658	7	9	11
Weight [kg]	**658**	**25.5**	**29.5**	**36.0**
Torso length [cm]	475	69.5	72.1	74.4
Shoulder width [cm]	475	27.2	29.0	30.7
Pelvis width [cm]	476	19.2	21.0	22.6
Chest [cm]	583	57.5	62.0	68.4
Waist [cm]	245	51.0	55.0	62.1
Abdomen [cm]	107	54.5	60.1	69.5
Hip [cm]	109	63.7	68.6	75.9

Table 4.
Different anthropometric data of German children with a body size of 144-146 cm. The second column shows the number of measured children. [database CrestNet 2006-2008]

Children body size 144-146 cm	N	percentile		
		5%	50%	95%
Age [years]	19104	8.7	10.7	13.5
Weight [kg]	**19104**	**30.4**	**37.5**	**53.3**
Torso length [cm]	425	73.2	75.9	79.0
Shoulder width [cm]	424	28.9	31.0	33.1
Pelvis width [cm]	427	21.0	22.6	24.6
Chest [cm]	537	61.5	66.7	78.0
Waist [cm]	223	53.3	58.1	70.2
Abdomen [cm]	103	58.9	64.0	79.8
Hip [cm]	113	66.6	73.9	86.1

Table 5.
Different anthropometric data of German children with a body size of 149-151 cm. The second column shows the number of measured children. [database CrestNet 2006-2008]

Children body size 149-151 cm	N	percentile		
		5%	50%	95%
Age [years]	567	10	12	14
Weight [kg]	**564**	**33.0**	**39.5**	
Torso length [cm]	382	75.3	78.1	81.1
Shoulder width [cm]	381	30.0	32.0	34.1
Pelvis width [cm]	384	21.6	23.5	25.7
Chest [cm]	472	63.0	69.3	80.4
Waist [cm]	178	54.3	60.1	73.8
Abdomen [cm]	75	56.6	66.5	82.4
Hip [cm]	91	68.9	78.3	89.0

OVERWEIGHT DUMMIES

The objective of this study is the evaluation of child restraint systems with *overweight* crash test dummies, weighing more than 36 kg. Currently, a lot of different child crash test dummies are available. A precise overview and technical specifications for

P-series, Hybrid III-series as well as for Q-series dummies can be found in the internet [3]. Only a weighted version for the Hybrid III 6 year dummy is available (115 cm, 27.9 kg).
Although the assembly of the P-series dummies is less sophisticated than the Hybrid III dummies they are still utilized for ECE R44 compliant tests. For this reason, it was decided to modify a P10 dummy (see figure 3). The P10 (*P10 base*) has a size of 137.9 cm and weighs 32.6 kg.

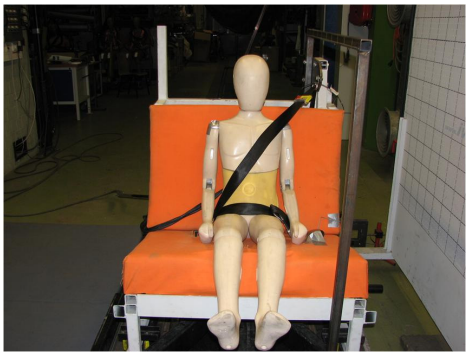

Figure 3. Standard P10 (*P10 base*) dummy belted on standard test device without child restraint system.

Three new dummies were defined (*P10 heavy*, *P10 large* and *P10 large and heavy*). Their technical data are summarized in table 6. The weights of the *P10 base* and of the *P10 large* represent the 50% percentile whereas the *P10 heavy* and the *P10 large and heavy* are 95% percentile versions (see table 4.). As children with a size of 150 cm are no longer legally obligated to use child restraint systems the *large* versions of the new dummies are restricted to a size of 145 cm.

Table 6.
Weights and heights for the P10 dummy and three modified versions.

dummy	weight [kg]	height [cm]
P10 base	32.6	137.9
P10 heavy	45.3	137.9
P10 large	37.5	145.0
P10 large and heavy	53.3	145.0

Basic dummy data
Technical data like 3d surfaces and weights of all dummy components are not commonly available, therefore the *P10 base* was scanned in detail. Using an optical 3d surface scanner the outer surfaces of all dummy parts were scanned. The skeleton of the dummy was x-rayed. Based on this data a complete 3d-Catia model of the dummy was built. Results are shown in figure 4.

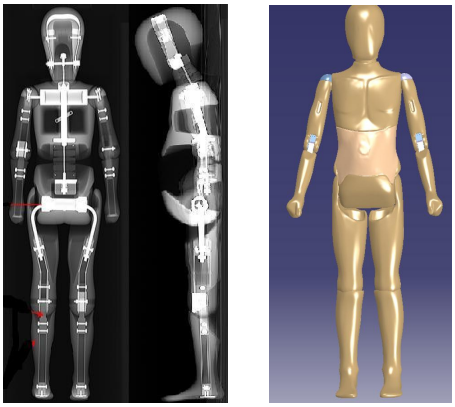

Figure 4. P10 (*P10 base*) dummy x-rayed in 2 views (left) and 3d-Catia model of the total assembly (right).

The net weights of all parts were measured necessarily. The 2 heavy versions were weighted proportionally to the reference weights. Exemplarily table 7 shows the weights of the subassembly leg.

Table 7.
Subassembly leg: weight of all parts and percentage of the total weight

#	Name	quan-tity	weight [g]	%
1	Hip ball joint	1	14,00	0,04
2	Hip joint nut/socket	1	143,90	0,44
3	Upper leg	1	3647,90	11,19
4	Lower leg	1	2566,75	7,87
5	Knee tensioner bolt	1	12,40	0,04
6	Knee tensioner nut	1	2,25	0,01
7	Friction washer	2	2,25	0,01
		total	6389,45	19,60

Overweight dummies

In order to weight the dummy torso and head additional metal plates are mounted to the rigid structure of the dummy. An additional jacket extends the girth of the torso. Shoulder and pelvis width remained unchanged. A proportional elongation of the torso height is necessary for the large versions of the new dummies. A new spine cable and additional elements for the lumbar vertebrae assembly increase the length. The foam abdominal insert is adapted respectively.

A simple modification of the extremities is not possible. Therefore, completely new arms and legs were manufactured. On the basis on the P10 extremities new parts were designed so that weight and length correspond to the new defined dummies as described in table 6. Exact data for the lower legs is given in table 8.

Table 8.
Lower leg assembly: Weights and lengths for the P10 dummy and three modified versions.

lower leg	weight [g]	length [mm]
P10 base	2567	385
P10 heavy	3566	385
P10 large	2953	404
P10 large and heavy	4197	404

The skeleton parts were scaled only in length for the large dummy versions. Therefore, the weight gain results, especially for the heavy versions, from an increased portion of the flesh. As the flesh is modeled with the original two-component polyurethane the volume of the heavy extremities was scaled up. Pictures in figure 5 and 6 show the new legs and lower arms.

OUTLOOK

Different types of child restraint systems will be inspected with the P10 and the new versions of the P10 according to UN-ECE Regulation No. 44. All selected CRS belong to ECE group II (15-25 kg) as well as to group III (22-36 kg). Some belong also to group I (9-18 kg). Figure 7 illustrates the differences between the seats. Combination seats allow children to use the same seat as they grow up.

Figure 5: Side view of four different left legs. From left to right: *P10 base, P10 heavy, P10 large* and *P10 large and heavy.*

Figure 6: Top view of four different left lower arms. From left to right: *P10 base, P10 heavy, P10 large* and *P10 large and heavy.*

Figure 7: Three typical CRS. From left to right: no-back booster seat (group II/III), high-back booster seat (group II/III) and combination seat (group I/II/III).

CONCLUSIONS

Statistical data clearly illustrate that for a lot of children not a single licensed child restraint system is

obtainable. Moreover, the crash performance of child restraint systems is completely unknown if they are used by children, weighing more than 36 kg.

Based on detailed anthropometric analyses the weight of real children in Germany was identified and new overweight dummies were defined. New dummy components were built so that the crash behavior can be tested in near future.

REFERENCES

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[3] www.ftss.com and www.radenton.com