MISUSE OF RESTRAINT SYSTEMS FOR CHILDREN IN THE NETHERLANDS

C.C. Schoon, C.G. Huijskens & A.H. Heijkamp
SWOV Institute for Road Safety Research, Leidschendam, The Netherlands;
TNO Road Vehicles Research Institute, Delft, The Netherlands;
Ministry of Transport and Public Works, Department of Transportation and Traffic Research (DVK), Rotterdam, The Netherlands.

ABSTRACT

Road authorities in the Netherlands stimulate the use - more specifically, the correct use - of restraint systems. A clear insight into the frequency and type of misuse is important for better design of safety devices, for legislation and for adequate public information.
Commissioned by the Ministry for Transport and Publics Works, the SWOV and IW-TNO have carried out a research project to establish the extent and type of misuse of child seats and standard seat belts. This paper deals only with child seats (child restraints).
In the first stage of the project, a method for measuring misuse was defined. Assessments of injury potential were based on accepted criteria in combination with knowledge derived from extensive laboratory testing and accident data.
A special form and a rating system were developed to judge the overall severity of misuse.
In the second stage, a field study was conducted at parking areas of shopping centres, roadside restaurants and theme parks such as zoos. The use of child restraints in the cars of the visitors was observed by trained technical students. Data on some 500 child seats were collected.
Considering the overall results, the degree of misuse of child seats was considerable: for almost 70% of seats, serious errors were noted.
Recommendations are given concerning an internationally accepted and standardised method of measuring the misuse of child restraints.

1. OBJECTIVE

The Dutch government is very concerned about the safety of children and adults while travelling. They want to improve safety, to encourage the use of seat belts and child seats and reduce misuse of restraints.
The objective of this national study is to achieve a clear insight into the frequency and main type of misuse configurations to enable a better design of safety devices and instructions for use and assist legislation and adequate public information. In this paper, only the results of child restraint systems are given.

2. INTRODUCTION

Children must be transported safely in a car. The use of restraints for children aged under 12 years make this possible.
Two points are of importance in this regard:
- child restraints must be USED to increase child protection in cars;
- child restraints must be USED CORRECTLY, in accordance with manufacturers' instructions.

In 1990, the rate of usage in the Netherlands was relatively small: 51% of children aged under 5 years were transported in a safety device; 45% were placed in a child restraint and 6% wore a lap belt or a three-point belt. Child restraints must be anchored firmly to the car and the child must be firmly secured in the restraint. The effectiveness of child restraints during an accident is considerably reduced if they are used incorrectly. One study conducted recently in the USA by Kahane (1986) calculated the following figures for:
- correct use of child seats: effectiveness of 71%
- partially correct use: effectiveness of 44%
- entirely incorrect use: no effectiveness.

Figures of other countries on the incorrect use of child seats vary markedly. To illustrate two extremes: in the USA, incorrect use was established in 75% of cases in 1983. In Australia during that same year, a figure of 5% was noted (Nygren et al., 1987; Pediatrics, 1988; Janssen, 1987).
A number of reasons for the marked divergence in these figures can be suggested:
- there are no clearly described and internationally accepted definitions with regard to misuse;
- the type of child restraint and type of passenger car differ from country to country;
- differences in the methods of observation can influence the final result of the field study.

3. FIELD STUDY

In order to achieve a clear insight into the frequency and main type of misuse configurations of safety devices in the Netherlands, observations in the field were conducted during the 1990 Easter holidays and during the next two weekends.
To obtain a summary of incorrect use of safety devices during both short and long trips, observations were carried out at shopping centres (local travel), fun fairs like zoos and roadside restaurants (long distance travel).
The observations of children were carried out with the permission of the driver. The observations were performed by five teams of two trained assessors, spread throughout the Netherlands. Each team was supervised while the actual survey was in progress.

4. SURVEY METHOD

Division of the groups

In the Netherlands, the most commonly marketed child restraints used by parents are represented by the following groups:
Group 1. Baby restraints (backward inclination; babies up to approx. 9 months of age and weight up to 10 kg).
Group 2. Child restraints with harnesses (forward inclination; from approx. 9 months to 4 years of age and weight 9-18 kg).
Group 3. Child restraints with impact shield (forward inclination; from approx. 9 months to 4 years of age and weight 9-18 kg).
Group 4. Booster cushions (from approx. 4 to 10 years of age and weight 15-36 kg).

Criteria for the assessment of child restraints

It is important to distinguish between the common misuse configurations to the child in terms of risk (injury potential). Whenever possible, assessments of injury potential were based on accepted criteria, in combination with extensive laboratory testing and accident investigation experiences.

The effectiveness of a child seat can be divided into two main aspects:
- the manner in which the RESTRAINT is anchored to the car;
- the manner in which the CHILD is secured into the restraint.

Within the scope of these two main aspects, a closer distinction between factors concerning fitting and use of the child restraint was made. The general aspect of anchoring the restraint to the car is divided into:
- fitting in accordance with manufacturers' instructions;
- slack in the anchor belts.

The general aspect of putting the child into the seat is divided into:
- securing in accordance with manufacturers' instructions;
- freedom of movement of the child in the child restraint.

Finally, for each aspect, considering the variation in design between the child restraints, each group had to be examined on the basis of different criteria. These were defined for the purpose of the study by the Crash-Safety Research Centre TNO (Huijskens, 1991). Based on these criteria, a form was designed on which the measurement results for four types of seat could be noted (see Enclosure 1).
In general, each separate aspect listed on the technical form had to be assessed by the field observers in terms of "correct" use or "incorrect" use. The only aspect that needed to be measured was the (longitudinal) displacement of the top of the child restraints.

Protocol during measurement

All measurements were carried out at parking places. The assessors themselves stopped the drivers. Once the driver had agreed to participate in the survey, the passengers were asked not to adjust the child restraints in any way. Each selected car was escorted to a quiet place where the measurements could be carried out. The general survey questions were entered in a special form (see Enclosure 2).

Final assessment after the field survey

After the field study, a computer programme translated the observations "correct use" or "incorrect use" of the technical form into a final assessment according to the following system:
Each separate aspect was appointed a fixed error score (a weighted value between 2 and 10), applied in case of incorrect use (see Enclosure 3). The value of each error score was based on the probability and potential severity of injury caused by incorrect use of that particular aspect. Minor errors had a value of 2; the more serious the error, the higher the value awarded (up to 10). For correct use, the 'error' score was always "0". The total score of a restraint system was obtained by adding up the error scores of the different aspects. Values far in excess of 10 are possible.

The scale used to translate this total score into a final assessment was divided in three categories:

$\leq$ 4 points: correct use
5 - 9 points: partially correct use;
$\geq$ 10 points: incorrect use.

Examples:
- if all aspects were correct, the total score was 0 (assessment: correct use);
- if only one or two aspects of minor severity (value 2) were incorrect, the total score was 2 or 4 (assessment: still correct use);
- if three or more minor errors were detected, the total score would be more than 4 (assessment: partially incorrect use, or incorrect use);
- if one or more very serious errors were found, the total score was 10 or more (assessment: incorrect use).

5. RESULTS

In total, 493 observations and measurements of child seats were carried out, with the following distributions based on seat location:
- front right: 26 (5%)
- left rear : 150 (30%)
- centre back: 103 (21%)
- right rear: 214 (44%)

Some seat types were often encountered, others rarely:
Group 1. Baby seats (rearward facing): 31 (5%)
Group 2. Seats with harness belts: 356 (72%)
Group 3. Seats with shields: 79 (16%);
Group 4. Booster cushions: 27 (6%).
It was striking to note that seats were rarely encountered for the youngest (Group 1) and oldest group of children (Group 4). It is assumed that the fourth group is not often seen, in fact. Contrary to expectations, the baby seat was not noted as often, either; this could be related to the choice of study location (fun fairs and shopping centres), where people might not often take babies.

The frequency of age of the children divided according to type of seat is given below:

Type of seat	Age (years)					
	<1	1+2	3+4	5+6	7+8	Total
1. Babyseat	29	2				31
2. Seat with harness belt	24	261	60	9	2	356
3. Seat with shield	1	38	33	5	2	79
4. Booster seat		4	14	9		27
Total	54	305	107	23	4	493

The following table includes the result of the measurements, classified according to type of seat.

Misuse of each type of child seat

Type	Correct (≤4 points)			Part. correct (5-9 points)			Misuse (≥10 points)			Total	
	n	%	margin % *)	n	%	margin % *)	n	%	margin % *)	n	%
1. Babyseat	13	42	±18	7	23	±15	11	35	±17	31	100
2. Seat with harness belt	55	15	± 4	33	9	± 3	268	75	± 5	356	100
3. Seat with shield	25	32	±10	9	11	± 7	45	57	±11	79	100
4. Booster seat	11	41	±19	0	-	-	16	59	±19	27	100
Total	104	21	± 4	49	10	± 3	340	69	± 4	493	100

*) 95%- level of confidence

If we consider the overall result, we see that 69% of child seats are used incorrectly, 21% are used correctly and 10% are used partially correctly. The differences noted between the seat types were considerable; the baby seat scored best: an error score of 35%. The type of seat with a harness belt scored worst: an error score of 75%. Due to the large proportion of the latter type of seat, the overall result for all seats had a high score for misuse.

The most frequently occurring errors fall into three distinct categories:
1. Errors in the ways child restraints are anchored to the car with the standard seat belts; either the routing of the belt was not correct (12%), or the buckle/tongue was located on a corner of the child restraint hardware, so that during a collision, it was likely to break open (33%).
2. Errors in restraining children with harnesses; an excessive slack in the child belts: for shoulder straps, this was noted for 41% of seats with a child belt, and for lap belts in 50% of cases.
3. Errors with respect to the forward movement of the top of the child restraint in relation to the backrest of the car; a quarter of the seats were fastened with a slack of 11-25 cm with respect to the backrest of the car; in six cases, slack in excess of 25 cm was measured.
It also appeared that in some cases, it was not even possible to anchor the child seat adequately, due to interfacing problems: the design and/or method of fitting the seat were not suitable for the car.

The seats often come with an approval mark offering technical information. Based on these facts, it could be examined to what extent the weight of the child in the seat agreed with the recommended mass group of the seat. For the entire group of child seats provided with an approval mark, 208 child restraints were correctly matched (86%). Of the 34 child restraints that were incorrectly matched (14%), the following errors were noted: in 47% of cases, the child was too heavy for the child restraint and in 53% of cases, the child was too light for the child restraint. In the latter case, it was often noted that a baby weighing less than 10 kg was put in a ECE Group 1 forward facing seat too soon.
In particular, small children seated in forward facing child restraint systems with a harness belt appear to be prone to tetraplegia in moderate frontal impacts.

There seems to be some relation between the distance travelled and the error score. Based on the assumption that in 2-door cars, the child seat is more difficult to anchor than in 4-door cars, it was expected that the error score for 2-door cars would be greater than for 4-door cars. This assumption proved to be incorrect, however. The difference between 2 and 4-door cars with regard to the error score is one half percent.
The differences between the error scores and the level of education of the driver are not great: the differences between the lowest and highest level of education for the "error" score is 10%. It was noted, however, that as the level of education rose, the error score dropped slightly.

6. DISCUSSION

Discussion concerning criteria and final assesment
The definition of "misuse" is a fairly complex one when applied to child restraints. Child restraints can either be fixed with a standard adult seat belt, or with a specific belt system. In addition, there are child restraints that offer a number of different user possibilities, the so-called combination systems. In this category, there are child restraints on the market which can be anchored in the car in no less than four different ways, depending on the type of car and the weight category of the child. If you add to this the number of possible positions (incl. sleeping position), 21 dynamic tests are needed to conform with the ECE 44 standard.

When drawing up criteria to assess all possible forms of incorrect use for all brands and types of child restraint, these matters play a role. In addition, insight into the degree of misuse and the frequency must be obtained from test locations spread throughout the country. This meant that many measurements had to be carried out, for which the utilisation of specialists would have been too expensive. The criteria therefore had to be adapted to suit trained assessors who, although they were not specialised, possessed sufficient technical insight.

If specialists were involved in the field work, they could have immediately awarded a final assessment for each child restraint. In order to arrive at a similar final assessment when carried out by non-specialists, a step by step method was followed. This comprised the following:
1. a simple questionnaire form, with a main classification according to the various types of child restraints, based on their design;
2. a questionnaire form which contains all parts and aspects that are relevant in assessing misuse separately;
3. a method to process the separate error scores into a final assessment.

re. 1. For the questionnaire form, we refer you to Enclosure 1. By choosing a classification on the basis of design and rearward/forward facing systems, the problem of the combined ECE groups (e.g. 0/1 and 1/2) was solved. Further subdivision relates to the types of child restraints that are most frequently sold in the Netherlands. This resulted in a form with only 4 main groups.

re. 2. The advantage of separately assessing the various aspects is that it sufficed to indicate whether each aspect was either "correct" or "incorrect". This made the observations by non-specialists easier.

re. 3. In order to arrive at a final assessment about the degree of protection offered if a child restraint is anchored incorrectly, an assessment system was designed, which is already described in Chapter 4. This system immediately awards a life-threatening error with the highest error score of "10". One or two less serious errors give a final assessment of "partially correct".

This assessment system is subject to discussion. In the first place, fixed criteria for scores applicable to each aspect are lacking. Knowledge on the basis of experiments and accident studies is still too limited. An estimation of the likelihood of serious injury in case of misuse was made as far as was feasible. In the second place, it is questionable whether a system of adding up separate scores to arrive at a final evaluation leads to the desired result. In some cases, two less serious errors would indeed lead to such an accumulation of points that this would imply entirely incorrect use, although this may not apply in general.
Once more knowledge becomes available, the system can be further perfected.

There is a need for an internationally accepted and standardised method of measurement in order to establish the misuse of child restraints in everyday practice. Only then can the results of field studies be compared with each other and can more pressure be brought to bear on industry in order to improve unsafe designs.

Based on the field study carried out in the Netherlands, the following recommendations can be made to further standardise the method of measurement:
- expand the questionnaire form for child restraints used outside the Netherlands;
- discuss in an international context: firstly, the criteria used to assess misuse of the various aspects distinguished, and secondly, the method used to arrive at a final assessment of a particular child restraint. The measurement method discussed here offers an impulse in that direction;
- process recent results of dynamic experiments and accident studies to perfect the method used to establish the misuse of child restraints.

Discussion concerning reasons for misuse
Looking at the reasons for misuse, a division into three categories can be made:
- insufficient information "how to use the restraint correctly";
- very complex restraints, which increase the risk of misuse;
- interface problems between the car and the restraint.
During this study, no information was gathered about misuse as a result of habits or motivation.

To prevent the observed cases of misuse, a few remedial actions are suggested. With respect to the information supplied, the manufacturers of the restraint systems could be stimulated to produce a very simple manual. The information should make the right (correct) way obvious. A permanent label on the child restraint is necessary. The development of symbols suitable for the child restraint is advisable.
The intention of the manufacturers should be to design a non-complex restraint, which can only be used in the correct way.

With respect to the interface problems, there are several ways to promote coordination, for example through better consultation between car and child restraint manufacturers and by stimulating the application of integrated systems.
In addition to all abovementioned actions, the public/users should be informed about how to select the optimal child restraint for their car. In the first place, car manufacturers and/or car importers should offer a recommendation in the car manual concerning the most suitable child restraint for their particular make of car. In addition, a checklist can be developed listing the important aspects concerning correct fit of the child restraint.
With respect to misuse as a result of wrong habits or wrong motivation, potential users should be informed and/or stimulated to use restraint systems and to use them correctly.

7. CONCLUSIONS

The degree of incorrect use of child restraints is extremely high: for almost 70% of seats, serious errors were noted. These errors can be classified into two main categories. Firstly, children are not held firmly enough by the belt: there is a danger that they will be thrown out of their seat during a collision. Secondly, the seat is incorrectly anchored: it was noted that this is not always the fault of the parent, but also because the seat was not appropriate for the car. The asymmetrical placement of anchoring points in a longitudinal direction and the improper location of the seat belt buckle (both in relation to the technical design of the child restraints) can be indicated as the main cause of the problem. Results are obtained for types of misuse that distinguish between technical and human failure. The results of the study can be used for three corrective actions:
(1) Advise the manufacturers with regard to an ergonomic design (belt and child restraints). Incorporate recommendation in car manuals for the most suitable child restraint. Encourage the manufacturers of child seats to produce clear manuals.
(2) Encourage the ECE-regulations (14 and 16) to pay more attention to installing child restraints using standard fitted adult belts.
(3) Advise the public (users) about correct and incorrect use of child restraints. For buyers, a checklist can be helpful, giving the important aspects for a correct fit of a child restraint in a car.

There is a need for an internationally accepted and standardised method of measurement of the misuse of child restraints, which would allow comparison of field study results. The method described here can be considered as a start. Discussions in an international context and more knowledge about the criteria should help to refine the method.

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CHILD SAFETY SEATS

ENCLOSURE 1

Chart [3]

Licence plate [ ][ ]-[ ][ ]-[ ][ ]

General codes
1 = correct
2 = wrong
8 = not appl.
9 = unknown

Seating position: [1] [2] | [3] [4] [5] | [6]

BABYSEAT (REARWARD) [1]

Seating position

Rearward/forward
1. rearward facing
2. forward facing

Anchorage points used

Car belt
Routing lap part

Routing shoulder part

Slack

Child belt

Buckle
All parts in buckle

Buckle is visible

Shoulder parts
Lateral slack

Shoulder parts in slots:
1. right slots
2. wrong slots
3. not enough slots

Position relative to neck
1. not against neck
2. against neck
3. slots too close to each other

Position of adjustable buckle relative to shoulder

Stacking in buckle

Delta belt (crotch strap)
1. position child correct
2. position child too low in seat
8. not appl.

Harnass belt
Slack in lap part
1. no slack
2. slack
8. not appl.

Label
Make _____
Model _____ [ ][ ][ ]
Mass category _____ [ ]
Country E [ ][ ]
code _____

SEAT WITH HARNASS BELT [2]

Seating position

Anchorage points used
3. seat loose in car

Fixed with
1. separate belt (see A)
2. lap belt (see B)
3. three point belt (see B)

A. *Separate belts*
Correct belts used

Corectly fixed at seat

B. *Lap/3 pnts belt*
Routing belt

Position buckle
(on edge is wrong;bending fracture)

Lock off device
8. absent
1. present + used
2. present, not used

Slack between seat and passenger seat back
(distance in cm) 1) [ ][ ]

Child belt
Buckle
2. not all parts in buckle
3. shoulder parts under arm-pits
4. child loose in seat

Position buckle
1. on lap/upper legs
2. on abdomen

shoulder parts
Lateral slack

Shoulder parts in slots
1. right slots
2. wrong slots
3. not enough slots

Position relative to neck
1. not against neck
2. against neck
3. slots too close to buckle each other

Position of adjustable buckle relative to shoulder

Stacking in buckle

Lap parts
Slack in lap part
1. no slack
2. slack

Data of Label

SEAT WITH SHIELD (NO HARNASS BELT) [3]

Seating position

Anchorage points used

Fixed with
2. lap belt
3. three point belt

Car belt
Routing lap belt

Routing shoulder belt
1. over shield
2. in front of child
3. behind child seat

Slack between seat and passenger seat back (distance in cm) 1) [ ][ ]

Slack in shield
1. no slack
2. slack

Kangol Duoseat + Stahl Carli
Shoulder part
Slack
1. no slack
2. slack

Position relative to neck
1. not against neck
2. against neck

Lap part
Slack
1. no slack
2. slack

Shield closed
(only Stahl Carli)

Label
Make _____
Model _____ [ ][ ][ ]
Mass category _____ [ ]
Country E [ ][ ]
Code _____

BOOSTER SEAT [4]

Seating position

Anchorage points used

Fixed with
2. lap belt
3. three point belt

Car belt
Routing lap belt
(through belt guides)

Shoulder part through guides
1 = 1x, 2 = 2x, 3 = none,
8 = not appl.

Position buckle
(on edge is wrong; bending fracture)

Child relative to car belt
Shoulder part
Routing
1. in front of child
2. behind child

Slack
1. no slack
2. slack

Position relative to neck
1. not against neck
2. against neck

Lap part
Slack
1. no slack
2. slack

Label
Make _____
Model _____ [ ][ ][ ]
Mass category _____ [ ]
Country E [ ][ ]
Code _____

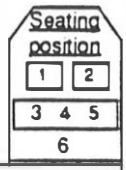
Remarks: 1) >77cm: code = 77

GENERAL FORM

ENCLOSURE 2

Chart [1]

Licence plate ☐☐-☐☐-☐☐



General interview data		Car and occupant data	
Time:	_____	Make:	_____
Date:	_____ ☐	Model:	_____
Site:	_____ ☐☐	Model year:	☐☐
		Number of doors (2 or 4)	☐
		Number of occupants	☐

QUESTIONS FOR ALL OCCUPANTS

	Driver	1st passenger	2nd passenger	3rd pasenger	4th passenger
Seating position	[1]	☐	☐	☐	☐
Lenght of travel (km)	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Male / femal, 1 = male, 2 = femal	☐	☐	☐	☐	☐
Age AA = 0-9 month BB = 9-12 month 01 = 1year etc.	☐☐	☐☐	☐☐	☐☐	☐☐
Lenght (cm)	☐☐☐	☐☐☐	☐☐☐	☐☐☐	☐☐☐
Education	☐	[8]	[8]	[8]	[8]
Belt/child seat used 1 = yes, 2 = no	☐	☐	☐	☐	☐

QUESTIONS ONLY IF CHILD SEATS WERE IN USE

		1st passenger	2nd passenger	3rd pasenger	4th passenger
Child's weight (only if child in seat)	[8][8]	☐☐	☐☐	☐☐	☐☐
Child seat					
Child seat is: 1. newly bought 2. second-hand 3. rented seat 4. borrowed	[8]	☐	☐	☐	☐
By whom fixed?: 1. private 2. garage/shop	[8]	☐	☐	☐	☐
Instruction available?: 1. yes 2. no	[8]	☐	☐	☐	☐

Remarks:

SWEDEN

ERROR SCORES OF INDIVIDUAL ASPECTS
(scores in case of misuse)

ENCLOSURE 3

CHILD SAFETY SEATS