INJURIES TO CHILDREN INVOLVED IN ROAD ACCIDENTS

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ABSTRACT

Results are presented of two investigations being carried out at the Transport and Road Research Laboratory into road accidents involving children; on the basis of these data some possible methods of protecting children are outlined.

The data indicate that children are injured less often in car accidents than adults and are safer in the rear seats than in the front. Safety restraints designed to current British Standards for children are effective in reducing the number and severity of injuries to child car occupants.

Laboratory research to reduce child pedestrian injuries by vehicle redesign is described.

1. INTRODUCTION

In 1972 16,345 children under the age of 15 years were killed or seriously injured on roads in Great Britain (2). This is 16 per cent of those of all ages killed or seriously injured. Fifteen per cent of those under 15 years were car passengers and 70 per cent were pedestrians.

Considerable work has been carried out on investigating injuries to adult car drivers and passengers; data and research on child injuries are more sparse and more recently work on pedestrian protection has been started. Safety belts for car occupants are designed principally for adults and for this reason may be unsuitable for children. The difference in requirements between adults and children has been recognised and in 1964 a section was introduced into the British Standard for seat belt assemblies (1) to cover restraints designed for children and restraints manufactured to this standard are widely used in the United Kingdom.

The purpose of this paper is to present and discuss some of the British data on injuries to children in road accidents and measures being taken to reduce this problem. The experience of child restraints is reviewed and the work on reducing pedestrian casualties is described.

2. SOURCES OF THE ACCIDENT DATA

The data on accidents and injuries used in this paper derive from three sources and it is important to bear in mind the selection of the sample when making comparisons between and within the tables.

The first source, referred to as investigation A, is an investigation being carried out by a multi-discipline team from the Transport and Road Research Laboratory consisting of medical scientists and engineers (3). Hospitals within an 80 kilometre radius of the Laboratory are visited regularly by

medical members of the team and any road traffic accident casualties that have been admitted are interviewed and medically examined. Their injuries are classified as minor, moderate or severe (4). No selection of casualties is made other than the fact that they have been admitted to hospital and were present at the time of the visit by the TRRL team. Admission to hospital puts them in the classification of serious injuries for the national road accident statistics of Great Britain (2). In the case of fatalities post mortems are attended and full details of all injuries are recorded.For the purpose of this paper, data from post mortems on pedestrians which were not attended have been used as well. Details are taken of all occupants of the vehicle involved in the accident.

The data in the second sample (investigation B) were obtained from the purchasers of child restraints. Questionnaires were supplied with some child restraint systems with the request that they be completed and returned to the Transport and Road Research Laboratory in the event of an accident involving child car occupants whether anyone was injured or not. The accidents in the sample were therefore, in general, of less severity than those covered by investigation A. The questionnaire replies are necessarily subjective and cannot be compared with data from other sources but useful comparisons within this sample can be made.

The third source of data is the national road accident statistics of Great Britain. Whenever an accident involving personal injury occurs on the public highway a standard comprehensive report form is completed by a police officer giving details of the accident and the injury to casualties. These data are stored on a computer and specific classes of accidents or injuries can be selected and tabulated. Selected tables from the accident data are published annually (2) and, where appropriate, tables from this publication have been used in this paper. Other tables of these data obtained for this paper are referred to as source C.

Information on the proportion of children wearing restraint systems and supporting information on the proportion of children sitting in the front and rear of vehicles were obtained from a survey carried out by the Laboratory at six locations in southern England covering a total of 5,000 children.

The age ranges used in different sources are given in Appendix I.

3. CHILDREN IN CARS

In order to make valid comparisons between children and adults, only passenger casualties have been considered in the following discussion. The results for drivers have been omitted unless otherwise stated.

3.1 Occurrence of injuries to children in car accidents

3.1.1 The variation of injury incidence with age. Comparison of the proportions of the total number of fatal and seriously injured casualties in each age range with the proportion in each age range normally found in cars on the road, indicates that there are fewer casualties in both of the lower age ranges than would be expected if occupants in the three ranges were equally at risk. (Table 1).

TABLE 1

Comparison of the distribution by age
of car passengers with serious and fatal injuries
with the distribution of car passengers by age
found in a national survey (5)

	0-3 years		4-12 years		13 years and over	
	No.	Perc-entage	No.	Perc-entage	No.	Perc-entage
Number and proportion of casualties in age range (source C: 1971)	505	2.5%	1163	5.7%	18625	91.8%
Expected exposure from Ref 5(sample of 1 days use of 8222 cars)		6.3%		14.1%		79.6%

One reason for the lower child injury rate in cars compared with adults may be that young children are usually driven by their parents and this often means by a driver in the age range 20 to 40 years. They probably rarely travel with drivers aged below 20 years who have been shown (6) to have an accident rate per kilometre of more than four times the average. In addition the accident rate after dark is about one third higher than that in daylight (7) and it is likely that fewer children will be in cars after dark than in daylight hours. It is not possible to estimate the effect of these factors in order to be able to determine from the statistics whether children are better able to withstand an impact than adults.

Table 2 compares the proportion of casualties with fatal and serious injuries who were sitting in the front and rear seats of the vehicle with the proportion found to be occupying those positions in cars in normal use on the roads.

TABLE 2

Comparison of the location of car passenger casualties
with the location of passengers observed in cars in normal use
(Fatal and serious injuries)

	0-3 years			4-12 years			13 years and over		
	Sample size	Front	Rear	Sample size	Front	Rear	Sample size	Front	Rear
Fatally or seriously injured casualties	427	51%	49%	975	35%	65%	15889	72%	28%
Estimated seat usage ref. 5		36%	64%		23%	77%		68%	32%
Seat usage observed in TRRL survey (unrestrained)	1523	37%	63%	2483	23%	77%			

This indicates that children are more likely to be injured when sitting in the front of the vehicle than when sitting in the rear. For adults, however, there appears to be little difference.

The figures in Table 3 also show that the injuries seem to be more severe to front seat casualties than to those in the rear. Although this difference is statistically significant for the older age group, it is not so for the children.

TABLE 3

Distribution of injuries to unrestrained vehicle passengers by severity for children and adults seated in the front and rear

Investigation A

Age	Seating position	Minor	Moderate	Severe or fatal
0-15 years	Front	3	19	5
	Rear	19	12	8
16 and over	Front	41	58	84
	Rear	38	37	30

3.1.2 Distribution of injuries to child car occupants. It might be expected that child casualties would present a different distribution of injuries from adults. Not only are children physically smaller than adults and likely to strike different parts of the car interior but compared with adults children have heads which represent a greater proportion of their body mass; about 14 per cent at 4 years and about 10 per cent at 12 years compared with about 7 per cent for an adult. Very young children have a smaller rib cage relative to the size of their body and a relatively larger unprotected abdominal area. It might therefore be expected that child casualties would show a higher incidence of injuries to head and neck and to the abdomen. However the results from investigation A do not seem to bear this out.

TABLE 4

Incidence of injuries (all severities) to various parts of the body expressed as a percentage of the total number injured: for unrestrained passengers in cars

Investigation A

Age(yrs)	Sample size	Region of body							
		Head	Neck	Arm and Shoulder Girdle	Back	Chest	Abdomen	Hip and Pelvis	Legs
0-15	52	73%	0	33%	2%	8%	13%	6%	46%
16 and over	288	87%	14%	47%	6%	34%	11%	12%	66%

Note: Totals in each age group are greater than 100 because of casualties with multiple injuries.

Table 4 shows the proportion of unrestrained casualties suffering injury to various parts of the body. It can be seen that the head is indeed the part of the body which most frequently suffers injury in children followed by arms and legs. The proportion suffering injury in the abdominal region is

not significantly greater than that for adults but those for injuries to the chest and neck are significantly less for children.

3.2. Restraint Systems for children

3.2.1 Design Requirements. Various restraint systems have been developed in order to reduce the number and severity of injuries to child occupants in car accidents. Many workers in this field (8-11) have pointed out the physical characteristics of children that must be considered when designing a safety restraint system for them in vehicles. A suitable restraint has to be designed to match the size of the child taking into consideration the strong and weak parts of the child's frame. This will usually mean that two or perhaps three systems have to be used from the period of infancy to the time that the child is large enough to be restrained properly by the adult belt.

Young infants are not able to support themselves in a seated position and, for these, carry cot type devices are available, held to the vehicle by straps and designed to prevent the child falling out of the cot during impact or when inverted.

When a child can sit up, it can be put in a properly designed and secured safety seat. This is usually a moulded bucket seat strapped to the vehicle and raised above the normal seat so that the child can see out of the vehicle more easily. A lap strap and shoulder straps should be used to spread the load to the stronger parts of the body. A young child has a more exposed abdominal area and does not have the fully developed iliac crests of the adult to provide good location for the lap belt. This part must therefore be carefully designed to prevent injurious loading of the abdomen during an impact. A crotch strap which does not itself impose a loading on the body but keeps the lap belt on the pelvis is often used for this. For forward facing seats the back of the seat should be high enough to give support to the head in at least rear impacts and preferably from side impacts also. Parts which can be contacted by the head must be designed to minimise injury.

Alternatives for the child at this stage are rearward facing seats (8), designed to spread the load from forward impacts over the whole of the upper back part of the body, and the individual padded shield type of protection (Tot Guard). Here the child sits behind a shaped padded impact shield which is held in place by an adult lap belt and is designed to cushion the forces of a forward impact over the upper front part of the body and head. These two alternatives are not widely used in the United Kingdom.

When the child is too heavy for these systems a child safety harness can be used. Here again the load must be applied to the strong parts of the body, and the lap strap must be designed to remain on the pelvis and not be pulled up onto the abdomen by tension in the chest or shoulder straps. Forward facing child seats and harnesses are the types of restraint most commonly available in the UK and these two devices constructed to a British Standard have been used for the past 10 years.

When the child is large enough an adult belt can be used provided the lap belt lies correctly on the pelvis and the diagonal part crosses the chest and not the neck or head.

3.2.2 Efficacy of current restraint systems. It can be seen from Table 5 that the proportion of casualties wearing restraints is less than that found on the road normally and therefore the restraint systems for children can be considered to be effective in reducing the numbers of serious and fatal

injuries.

TABLE 5

Comparison of the proportion of casualties wearing restraints with the observed wearing rate for car passengers. (Fatal and serious injuries).

	Sample size	Proportion of children aged 0-12 years wearing a restraint
Fatal or seriously injured casualties Source C : 1973	1386	5%
Random sample observed on the road in six towns in Britain(TRRL)	4466	12% (9.4% for BSI approved systems)

It must be emphasised that the wear rate figures are not sufficiently well established and that this approach is too simplified for these figures to be used to quantify the effectiveness of seat restraint systems in reducing injuries but they are useful for comparative purposes.

Another indication that restraint systems are effective is seen in Table 6. The probability of injury is significantly reduced by the use of a restraint system. The severity classification is not identical to those used in investigation A or source C.

TABLE 6

Distribution of injuries to children by severity from different types of restraint

Investigation B

	Sample size	No injury	Slight injury	Serious injury
No restraint	33	55%	33%	12%
Carry cot	11	73%	27%	0
Safety seat*	164	89%	10%	1%
Safety harness*	31	88%	6%	6%

*All in these categories were approved to the British Standard

There were 10 accidents reported in investigation B in which there were both a restrained and an unrestrained child. In seven cases in which the restrained child was uninjured, four of the unrestrained children were uninjured, one suffered a cut face and two a broken leg. There were two cases in which the restrained child suffered bruising. In one the unrestrained child also suffered bruising and in the other there were two unrestrained children, one suffered a bruised back and the other a fractured clavicle and serious chest injuries. In the last case the restrained child suffered a cut lip while the unrestrained child escaped injury. These results are summarised in Table 7 below.

TABLE 7

Injuries suffered by children in instances where there were unrestrained and restrained children in the same car

Investigation B

Restrained child	No. of cases	Unrestrained child in same car	No. of cases
Uninjured	7	uninjured cut face broken leg	4 1 2
bruised	2	bruised fractured clavicle and severe chest injuries	2 1
cut lip	1	uninjured	1

In order to obtain an interim estimate of the efficacy of child restraints a subjective assessment was made of accidents involving over 100 children studied in investigation A. It was concluded from consideration of the trajectory of the children in the accidents that if child restraints had been worn and correctly fitted then more than half of the serious injuries might have been prevented.

To determine if direction of impact on the car affects the efficacy of the restraint system, casualties have been selected from source C who were injured in a vehicle for which there could be defined a unique direction of impact. Comparison of the proportion of casualties wearing restraints (Table 8) suggests that there is little difference in their effect on fatal and serious injuries for the main directions of impact for both child and adult systems.

TABLE 8

The effect of direction of impact on the reduction of injuries (fatal and serious) brought about by wearing restraint systems

Source C: 1971

Direction of impact	Proportions of passengers with fatal or serious injuries, restrained and unrestrained					
	0-12 years			13 years and over		
	Sample size	Restrained	Un-restrained	Sample size	Restrained	Un-restrained
Frontal	404	4%	96%	4844	5%	95%
Rear	32	3%	97%	210	7%	93%
Side	114	4%	96%	999	6%	94%

4. CHILDREN AS PEDESTRIANS

4.1 Occurrence of injuries to children as pedestrians

4.1.1 The variation of injury incidence with age. Details for different classes and ages of road user are given in Table 9. It can be seen from the figures that, while injury to vehicle occupants is important, injuries received by children as pedestrians is a much more serious problem. Nearly 80 per cent of fatal or seriously injured road accident casualties between the ages of five and nine were pedestrians compared with a figure of about 28 per cent for casualties of all ages. The proportions are even higher if only fatalities are considered.

TABLE 9

Numbers killed or seriously injured by class of road user and age group

Ref 2:1972

Age Group (years)	Pedestrians		Cars, goods and psv		Others		All road users	
	Casualties	Casualty rate per million population	Casualties (Drivers and passengers)	Casualty rate per million population	Casualties	Casualty rate per million population	Casualties	Casualty rate per million population
0-4	2369	5.6	684	1.6	30	0.1	3083	7.2
5-9	5775	12.7	802	1.8	691	1.3	7268	16.0
10-14	3358	8.0	948	2.3	1688	4.0	5994	14.3
15 and over	15804	3.8	49812	12.0	17095	4.1	82711	20.0

3.1.2 Distribution of injuries to pedestrians. As for vehicle occupants, the difference in the size and weight distribution of children and adults means that they have to be considered as a separate case in pedestrian injury prevention studies.

Table 10 shows the distribution of injuries to various parts of the body for child and adult pedestrians.

TABLE 10

Injuries more severe than minor to various parts of the body as a percentage of the total number injured for pedestrians

Investigation A

Age (years)	Sample size	Head	Neck	Arm and shoulder girdle	Back	Chest	Abdomen	Hip and Pelvis	Legs
0-15	119	53%	6%	19%	1%	6%	8%	20%	46%
16 and over	424	41%	6%	22%	6%	19%	8%	24%	70%

Note: Totals in each age group are greater than 100 because of casualties with multiple injuries

The general pattern of injuries to children and adults is similar; injuries to the head being an important feature of both. Injury to the legs of adults, however, are much more common than to the legs of children and this difference is mainly due to the difference in size of adults and children, the legs being the part struck first on adults.

Five of the child pedestrian fatalities in investigation A were examined to attempt to ascertain the probable cause of death. In three cases the cause of death was attributed to head injury, one to neck injury and one double injury to the head and neck.

4.2 Vehicle modification to reduce injuries to child pedestrians.

Improvements in the design of vehicles from the point of view of pedestrian safety are being considered both to reduce lower limb fractures and other injuries. It has been shown (12) that a large proportion of fatal injuries to pedestrians were caused not by initial impact with the vehicle but by the secondary contact with the ground or by being run over. For this reason experimental work is being carried out at the Transport and Road Research Laboratory with the aim of producing a means of retaining the struck pedestrian on the bonnet of the vehicle. Figure 1 shows a six year old child dummy being struck by an early experimental design of pedestrian protection device. The vehicle is designed with a relatively soft, low point of initial contact with the pedestrian and a low leading edge to the bonnet. When the pedestrian is struck, he tips onto the bonnet and, in the experimental version, a bar is raised to prevent him sliding off into the road. Their small stature obviously presents a problem of ensuring that children are raised onto the bonnet after impact rather than being knocked down.

5. CONCLUSIONS

1. In 1972 in Britain, about 2400 children under the age of 15 were killed or seriously injured in cars.
2. In the same period about 11500 child pedestrians were killed or seriously injured.
3. Children in cars are significantly safer in rear seats than in front seats.
4. For children, both as car occupants and as pedestrians, the most critical injuries are those to the head.
5. Child restraint systems for car occupants need to be designed to suit the child's body.
6. There is evidence that correctly designed child restraint systems are effective in reducing injuries in all directions of impact.
7. For child pedestrians, retention on the car bonnet after impact shows a possible means of preventing final impact with the road surface and of reducing injuries from this cause.

6. APPENDIX I

Age Ranges

The British Standard for child restraint systems (1) differentiates between systems designed for children of 9 to 18 kilogrammes and those for children of 18 to 36 kilogrammes. These correspond to average children of about 4 years and 12 years old. In addition an average 12 year old child corresponds in height approximately to a fifth percentile female and should be

able to wear an adult seat belt satisfactorily. Consequently, where possible, age ranges of 0-3 years, 4-12 years and 13 and older have been chosen. In investigation A, data are recorded in age groups 0-5 years or 6-15 years for children, and in Reference 2 the figures are tabulated in age ranges 0-4 years, 5-9 years and 10-14 years for children. This means that comparison of relative numbers between tables is sometimes not possible but for the relative distributions within tables it makes little difference in practice.

7. ACKNOWLEDGEMENTS

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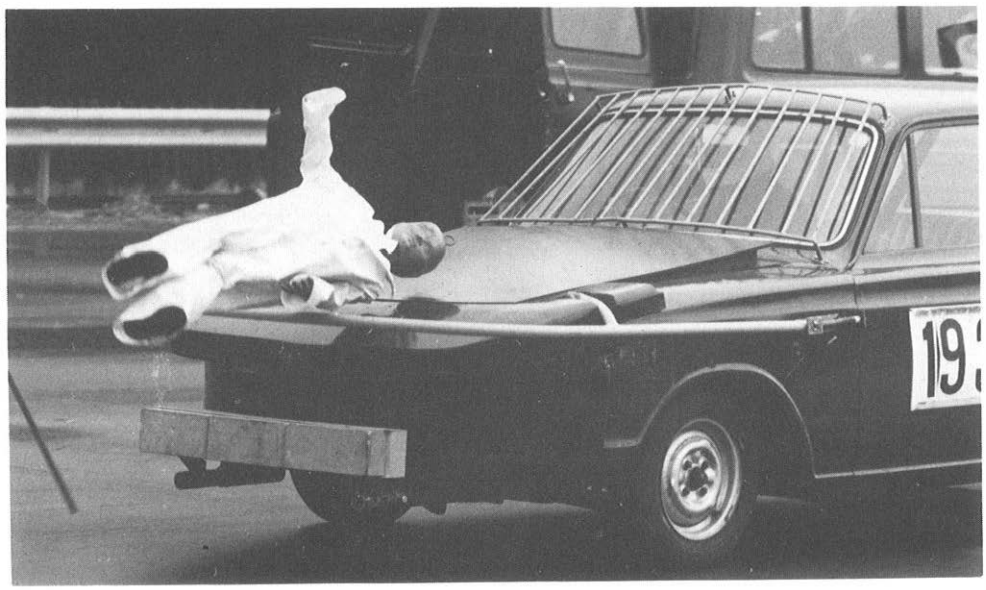

Figure 1

A six year old child dummy being struck by a vehicle with an experimental device attached designed to retain the pedestrian on the bonnet after impact