THE PROTECTIVE EFFECT OF CRASH HELMETS

- A Study of 96 motorcycle accidents -

by

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Introduction.

The modern motorcycle is an efficient and inexpensive means of transport to thousands of people and the amount by which it pollutes the atmosphere is relatively small.

As the price of petrol goes up and as rationing appears to be more and more likely in the future, the use of motorcycles will undoubtly increase. This can be seen in the developing countries, where the average income is so low that only very few people can ever hope to own a car. Many families therefore use a motorcycle as their daily means of transport.

Motorcycle riders belong to the category of unprotected road users and in case of an accident they are exposed to a severe risk of injury. All possible means of preventing injury must be utilized and in this connection the crash helmet is an important item.

Trends in accident statistics.

In a number of international reports from the United States, Switzerland, England and elsewhere, an increase in the number of people killed and injured in road accidents in recent years can be noted. This trend is considered to be due in part to an increased number of heavy and powerful motorcycles during this period and in part to a simultaneous revocation of helmet use laws in certain states in the U.S.

As a term of reference for the trends regarding fatalities and casualties in Sweden, the number of insurance years has been used. Owing to the high costs incurred by injuries, insurance premiums have become very high. The experience of insurance companies in Sweden is therefore that vehicle-owners nowadays

only insure their vehicles for the period during which they are used which in Sweden is only for a part of the year. The number of severely injured motorcycle riders has increased over the past 10 years, figure 1. The number of fatalities has decreased since 1974.

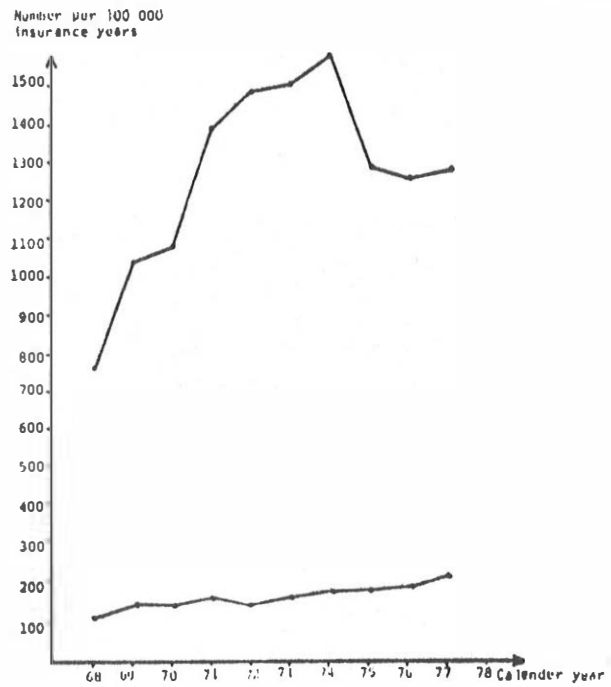

Figure 1. The number of motorcycle and moped riders severely injured per 100 000 insurance years in Sweden.

Legal aspects.

In sweden there are three types of power driven two-wheeled vehicles: mopeds, light motorcycles and heavy motorcycles. A moped has an internal combustion engine with a capacity of 50 cc and is designed for a speed of 30 km/h. Only with difficulty can it be modified to achieve higher speeds. If the capacity of the engine does not exceed 125 cc and the weight of the motorcycle without passenger does not exceed 75 kg, it is classified as a light motorcycle. If the engine capacity exceeds 125 cc it is regarded as a heavy motorcycle.

Both heavy and light motorcycles must be registered and drivers must have a licence. The minimum age limit for a light motorcycle is 16 years and for a heavy motorcycle 18 years. Mopeds may be driven without a driving licence from the age of 15.

Helmets.

Crash helmets used in Sweden are imported and are of comparatively uniform design. Two types are predominant: open face helmets (OF) and full face helmets (FF), table 1. The helmets consist of a shell, a shock absorbing liner, a

comfort padding, a chin strap, and as optional equipment a peak or a vizor. The design is determined to a large extent by the national standard SIS 882411.

Modern helmet shells are made of a plastic material that may be either of two kinds: a thermosetting plastic or a fibre glass reinforced polyester. Thermosetting plastics include ABS and polycarbonate. The advantages of polycarbonate are that it displays good resistance to impact and is comparatively cheap. Disadvantages are that it is elastic and under certain conditions may become brittle.

Helmets of fibre glass reinforced polyester are manufactured by a different technique with a larger proportion of manual work and consequently more expensive than moulded helmet shells. If the fibre-glass reinforced helmet is subjected to an impact it mainly deforms in a plastic way. Helmets of all three types that have been exposed to external violence in an accident may have lost their protective effect.

The shock-absorbing liner consists of expanded polystyrene. In order to protect the head of the wearer during an accident, the helmet is designed to undergo deformation and thereby provide a certain stopping distance for the head during an impact. The protective effect is achieved in that both the helmet shell and the liner can be deformed.

Material and methods.

In the present study, accidents occurring during the period November 11, 1975 - - September 20, 1978 among motorcycle riders insured with Folksam have been investigated. During the investigation period, 25% of all motorcycles and 22% of all mopeds in Sweden were insured with Folksam. This corresponds to approx. 7 500 insurance years for motorcycles and approx. 75 000 insurance years for mopeds.

Since the wearing of crash helmets by motorcyclists was made compulsory, Folksam has paid indemnity for damaged helmets. Helmets redeemed in this way by Folksam have been examined at the Department of Traffic Safety, Chalmers University of Technology, Gothenburg, where it has been possible to compare helmet damage with the associated head injury, table II.

Table I. Types of helmets used by the riders of the different types of vehicles.

Moped riders			Heavy motorcycle riders		
OF-helmets	12	100%	OF-helmets	8	22%
			FF-helmets	29	78%
Light motorcycle riders			**Type of vehicle unknown**		
OF-helmets	13	43%	FF-helmets	4	
FF-helmets	17	57%			

Police reports and insurance documents were studied for 83 non-fatal accidents

and the riders were interviewed over the telephone. 91 helmets from these accidents were available for examination. In 13 fatal accidents the autopsy reports and hospital records were also studied. From these accidents the helmets were not available.

Table II. Extent of the investigation.

Number of non-fatal accidents investigated	83
Number of fatal accidents investigated	13
Total number of accidents	96
Number of helmets examined (from non-fatal accidents)	91
Number of drivers	82
Number of passengers	9
Number of injured drivers	74
Number of injured passengers	8
Number of riders with head injuries	40
Number of non-injured riders	9

Fatalities occurring during the observation period.

During the observation period 87 persons received fatal injuries as a result of motorcycle accidents in Sweden. Fourteen of them were Folksam policy-holders. Type of accident and leading cause of death for these are shown in table III.

Table III. Fatalities in motorcycle accidents insured with Folksam, 13 drivers and 1 passenger.

Type of accident	Number	Causes of death
Single-vehicle accident	6	Head injury(3), spleen injury(1), injury to larynx(1), ruptured aorta(1)
Collision with car	2	Head injury(2)
-"- -"- lorry	4	Heart injury(1), head injury(1), ruptured aorta(1), internal bleeding(1)
-"- -"- cycle	1	Rupture in the liver(1)
-"- -"- train	1	Traumatic amputation of one leg (1).

The autopsy reports show that in six of these fourteen fatalities the leading cause of death was a head injury. These injuries were the result of violent blows to the crown of the head causing multiple fractures and brain lacerations. All deceased persons wore crash helmets but these helmets have not been available for examination. However, from the police reports and other insurance documents it appears that in this type of very violent, high speed accidents even the best helmets can offer but minimal protection and cannot prevent the fatal outcome.

Accident types.

The most frequent type of accident for all types of two-wheelers was a collision with another vehicle and in the majority of cases the other vehicle was a motor car. Single-vehicle accidents were, however, also frequent with this type of inherently unstable vehicle. It is interesting to notice that in three accidents there was a collision with an animal, table IV. The annual number of police reported road accidents with animals involved is increasing in Sweden and reached in 1977 a total of 480 accidents.

Table IV. Types of accidents for the 91 examined helmets

Accident situation	Drivers	Passengers	Total
Motorcycles.			
Single-vehicle accident	16	4	20
Collision with car	38	3	41
-"- -"- motorcycle	4	1	5
-"- -"- moped/cycle	2	-	2
-"- -"- buss	1	-	1
-"- -"- tractor	2	-	2
-"- -"- animal	3	1	4
	66	9	75
Mopeds.			
Single-vehicle accident	5		
Collision with car	6		
-"- -"- moped	1		
	12		
Type of accident unknown	4		

Accident sequence.

In order to describe the accident sequence, i.e. the risk of injury that riders are exposed to the following classification has been used:

1. Impact against a fixed or movable object where the rider comes to rest at the site of the impact (21 cases).
2. Impact against the ground or road surface at some distance from the site of impact or loss of control (67 cases).
3. One case where after collision with a bus the rider fell under it and one of the rear wheels ran over his helmet (1 case).
4. Accident sequence unknown (2 cases).

Table V. AIS rating of all injuries to 91 surviving two-wheeler riders.

1. Impact against an object (21 cases)

Body region	AIS rating 1	2	3	4	5	Number of injuries
Head	5	6	2	1	1	15
Neck	3	-	-	-	-	3
Face	4	1	2	-	-	7
Teeth	-	1	-	-	-	1
Upper extr.	4	3	-	-	-	7
Lower extr.	8	4	1	-	-	13
Chest	-	1	2	-	-	3
Pelvis	-	-	2	-	-	2
Back	2	-	2	-	-	4
General	1	-	-	-	-	1
Ear	-	1	-	-	-	1
	27	17	11	1	1	57

2. Impact against the ground or road surface (67 cases)

Head	12	12	1	-	-	25
Neck	9	-	-	-	-	9
Face	3	-	-	-	-	3
Teeth	-	-	-	-	-	-
Upper extr.	10	14	-	-	-	24
Lower extr.	14	8	4	-	-	26
Chest	-	-	-	-	-	-
Back	3	-	1	-	-	4
General	6	-	-	-	-	6
Ear	-	-	-	-	-	-
	57	34	6	-	-	97

3. Rear wheel over the helmet (1 case)

Hip	1	-	-	-	-	1

4. Type of accident unknown (2 cases)

Speed.

The speed at the time of the accident was estimated by the driver of the two-wheeler. It was unknown in twelve cases, four of these had sustained head injuries (AIS 1 = 1, AIS 2 = 2 and AIS 5 = 1). In four cases it is not known whether a head injury had occurred or not.

Of the twelve moped riders, eleven were travelling at a speed below 30 km/h and one had 40 km/h (AIS = 2, AIS2 = 2).

In sixtyseven motorcycle accidents only five riders sustained severe head injuries AIS 3-5, four of these were travelling at a speed above 40 km/h and one could not remember his speed due to a concussion.

The AIS-ratings for the head injuries in accidents at various speed intervals are shown in figure 2.

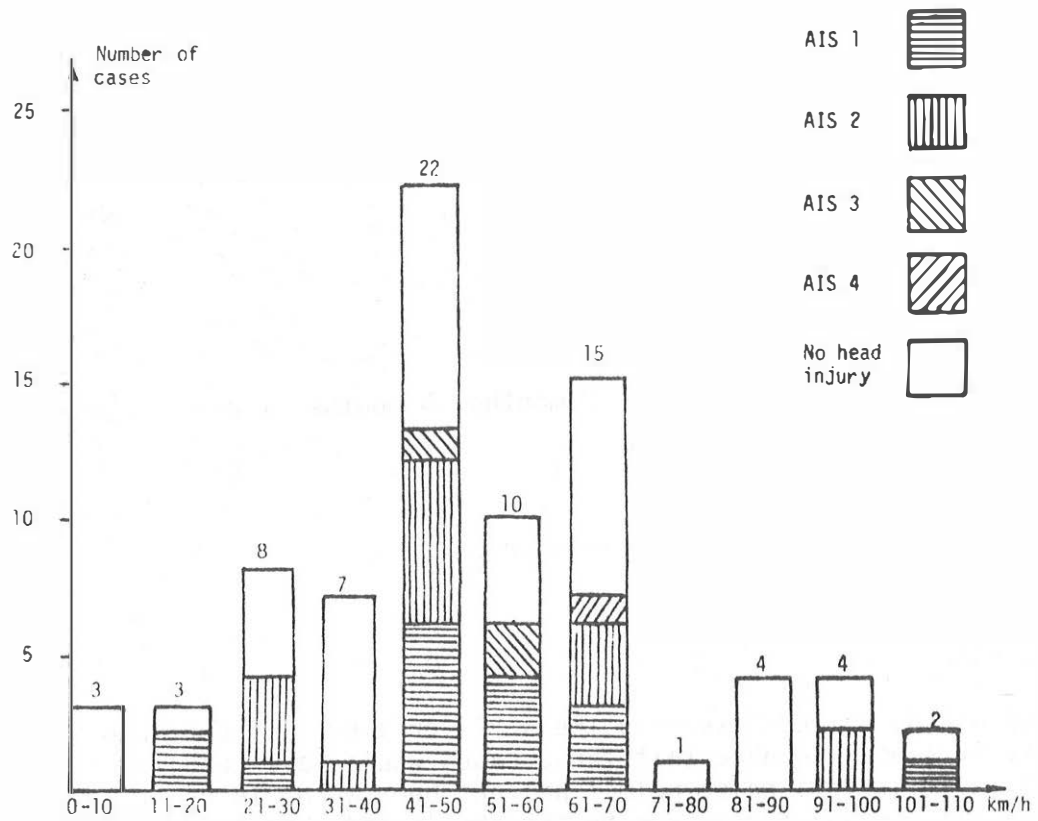

Figure 2. Distribution of speed and AIS rating for the head injuries in 79 cases. In 12 cases the speed was unknown.

Age.

66% of the moped riders were only age 15 and had had their mopeds for less than six months. 63% of the motorcycle riders were under age 20 and had had a drivers licence for less than four years, table VI. This shows that the material is dominated by young and inexperienced riders.

Table VI. Distributions of age of drivers and length of time they have had their driving licenses or owned their mopeds.

Age of motorcyclists (66 cases)

Years	16-17	17-18	19-20	21-25	26-30	31-40	41-50
Numbers	6	22	14	18	3	2	1

Age of driving licence (66 cases)

Years	.5	1	2	3	4	5	6	7	8	9	10	12	28
Numbers	7	16	8	8	8	8	2	2	1	2	1	2	1

Age of moped riders (12 cases)

Years	15	16	17	53
Numbers	8	2	1	1

Moped ownership (12 cases)

Owned moped	1 day	1 month	2 months	6 months	1 year	3 years	20 years
Numbers	1	1	1	5	2	1	1

The age of 4 motorcyclists were unknown.

Discussion.

In 40 of the helmets examined the shell or liner was deformed by a direct impact. It seems probable that these cases would have resulted in more serious head injuries if a crash helmet had not been worn. In 44 helmets there was some kind of abrasion damage to the shells and then the corresponding injury to an unprotected head is more difficult to judge. Head injuries and/or a deformed liner were found in 21 of these cases and it seems likely that the head injuries would have been more serious if a helmet had not been worn. Consequently it can be considered that at least 61 persons (approx. 65%) would probably have sustained more severe injuries if they had not been wearing a crash helmet.

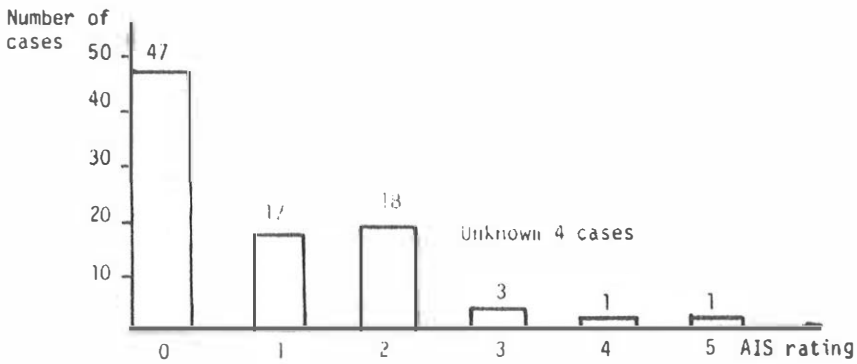

Figure 3. AIS rating for the head injuries in the non-fatal cases.

Figure 3 shows that 40 persons suffered head injuries and that only five of them were of a serious nature, i.e. AIS 3-5. In a motorcycle accident a crash helmet is therefore assumed to provide protection. Of the others, 22 were injured, AIS 2-5 in the face or neck, figure 4. In these cases the crash helmets have probably protected the wearers from head injury since all the helmets in these cases displayed some form of damage.

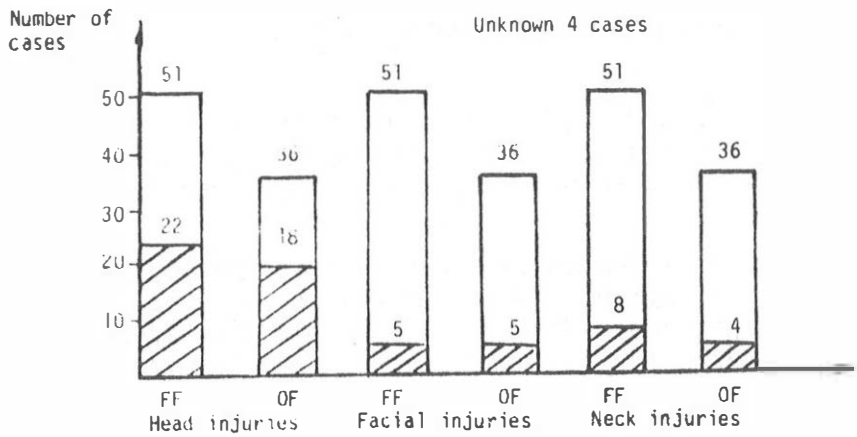

Figure 4. Distribution of head, face and neck injuries between the two types of helmets (FF= full face and OF = open face helmets).

Full face helmets seem to provide somewhat better protection against head injuries and facial injuries than open face helmets.

Different helmet materials.

On correlating head injuries with different helmet shell materials it would appear that fibre glass reinforced polyester provides somewhat better protection against such injuries, figure 5.

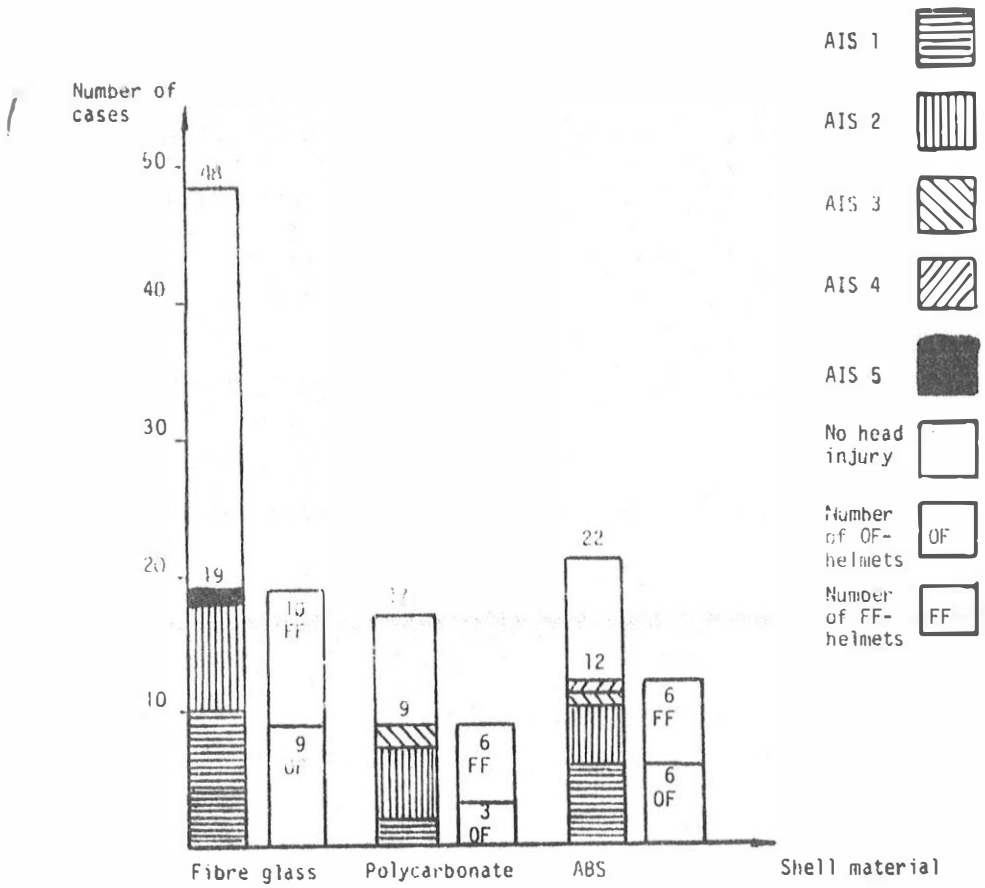

Figure 5. 40% of wearers of fibre glass reinforced helmet shells had some kind of head injury the corresponding figures for the other shell materials were 53% for polycarbonate and 55% for ABS.

The fibre glass reinforced polyester shells seemed to be somewhat better than the shells of thermosetting plastic materials. This could probably be attributed to the fact that they deform in a more plastic way which may result in a lower velocity change for the head than in helmets with more elastic shell materials. However, this is the case only if both the shells and the liners are permanently deformed and thus provide a sufficient stopping distance for the heads. If only the shells and not the liners were damaged it was not possible to find any difference in head injuries between wearers with helmets which had different shell materials, figure 6.

Among the helmets connected with head injury there were 24 (60%) which did not display any kind of deformation of the liner. This might be because the helmets are too stiff or because rotational acceleration lowered the tolerance to linear acceleration, as indicated by Ommaya (1971), table VII.

Table VII. Head injury AIS correlated to damage to the shell or the liner.

Damage to the shell	Deformed liner	Undamaged liner
Hole or crack	AIS 0 = 4 AIS 1 = 6 AIS 2 = 5 AIS 3 = - AIS 4 = 1 AIS 5 = -	AIS 0 = 7 AIS 1 = 2 AIS 2 = 3 AIS 3 = 1 AIS 4 = - AIS 5 = 1
Abrasion	AIS 0 = 3 AIS 1 = - AIS 2 = 4 AIS 3 = -	AIS 0 = 30 AIS 1 = 9 AIS 2 = 5 AIS 3 = 2
Non	-	AIS 0 = 4 AIS 1 = - AIS 2 = 1

Unknown 3.

In helmets where the liner had not been damaged no difference could be seen between the percentage of head injuries in the three groups with different shell materials, figure 6.

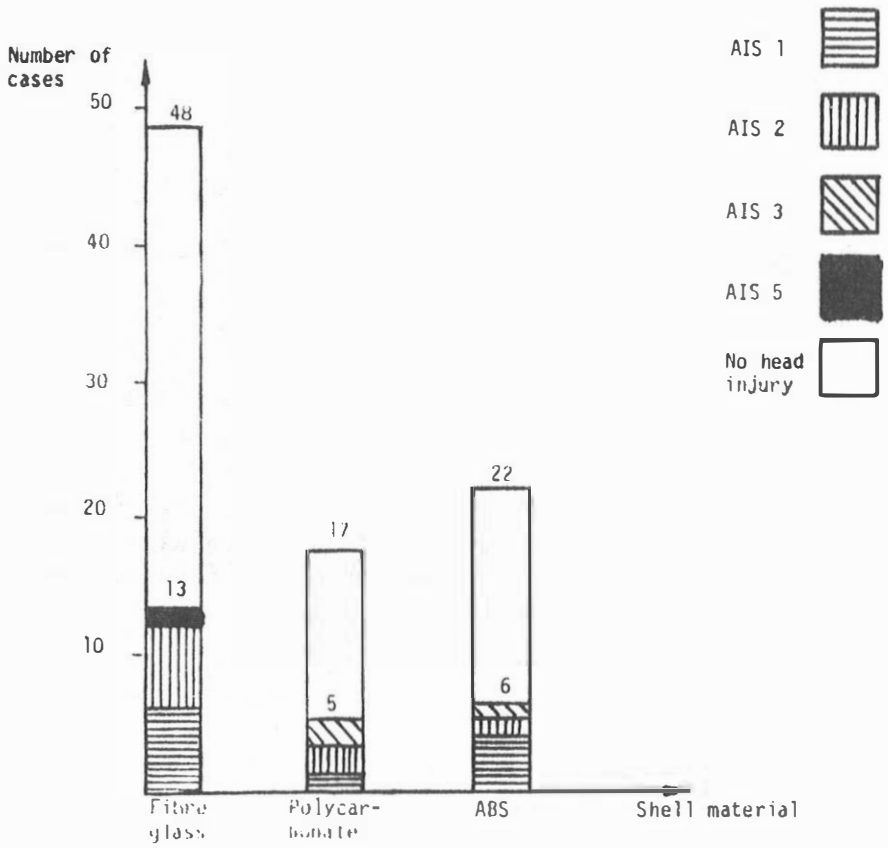

Figure 6. 27% of wearers of fibre glass reinforced helmet shells had some kind of head injury the corresponding figures for the other materials were 29% and 27%.

Possible improvements of crash helmets.

Since some cases display head injuries without deformation of the helmet liner its protective effect has obviously not been optimal. Further improvements to the design of crash helmets might lead to a decreased severity of head injuries, which would result in less serious late effects. In the fatal cases, the possibilities of reduction of the injury severity are small since these often concern accidents at very high speed with extensive damage to the head and neck.

Conclusions.

1. Motorcycle and moped riders who have been involved in accidents are often young and inexperienced people. Stricter examination of riding skills and possibly a reduction of the very high speeds with heavy motorcycles could conceivably have an effect.

2. Full face helmets provide protection against head and facial injuries. One disadvantage is their weight. With regard to different helmet materials, none of those available appears to be optimal. A reduction in helmet weight and further improvement of the shock-absorbing ability are therefore considered to be of principal interest in the future development of crash helmets.

Selected references.

Ommaya,A.K., Hirsch,A.E. (1971): Tolerance for cerebral concussion from head impact and whiplash in primates. Journal of Biomechanics, 4, 13.

Vaughan,R.G. (1977): Motorcycle helmets and facial injuries. The Medical Journal of Australia, Jan. 1977, pp. 125-217.

OECD Road Research Group (1978): Safety of two wheelers. A report prepared by an OECD road research group, March 1978.

US Department of Transportation News. Jan. 11, 1979.

Vallin,J.M., Veaux,M. (1977): Etude sur les methodes d´essai des casques pour conducteurs de vehicules a deux roues et sur la qualite des materiaux constituant des casques, Laboratoire National d´Essais, Paris.