THE INFLUENCE OF PROTECTION HELMETS IN MOTORCYCLE ACCIDENTS

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ABSTRACT

Approximatively 7oo ooo bicycle scooters (mopeds) are registred in Switzerland (engine displacement 5o ccm,top speed 3o km/h,no licence).They may be driven by persons older than 14 years.Over 1o % of all traffic fatalities in Switzerland involve drivers of these vehicles.

133 drivers were killed in 1975 and 4491 severely injured.Detailed results of a one year study of all accidents involving these mopeds in the city of Zürich are presented.As in accidents with heavy motorcycles the most frequent cause of death is a trauma of the skull and / or the brain.Therefore headinjuries are analysed whereby special atention is given to drivers protected by helmets. Integral helmets seem to give the best protection.

The standard procedure of testing helmets in Switzerland is discussed.The conditions under which a helmet is pushed away by a wheel rather than rolled over are examined.For this purpose some aspects of the interaction between helmet wheel and ground are investigated mathemathically and experimentally.It is shown that the main parameters are the angle between wheel direction and the tangent plane in the contact point of the helmet as well as the diameter ratio between wheel and helmet.

1. INTRODUCTION

Motorcycle accidents were treated in several international reports (1,2,3,5,6, 7,9,11).Nearly all of them showed an increase of frequency and severity of these accidents.Also in Switzerland the largest increase in the number of persons injured in traffic accidents is seen with the category of motorcycles, especially bicycle scooters (16).Since 1963 the rate of injured scooter drivers dubled wheras that of car occupants increased by 48% and that of heavy motorcycle drivers by 12%.A similar situation presents itself with regard to the fatalities on the road.

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Drivers of scooters showed the highest rate of headinjuries of all persons involved in traffic accidents followed by car occupants and pedestrians.Yet a very low number of scooter drivers wear protection helmets in contrast to drivers of heavy motorcycles.
The protection effectivness of helmets has been documented in various publications (1,2,3,4,5,7,8,9,12,13,14,15).Little attention has been given in the literature to the mechanical behavior of a helmet during the crash.Richardson (12)pointed out that 12% of the helmets were separated from the head during the accident,half of them before the impact of the head to the concerning object.This was due to a bad fastening or a failure of the chin strap.

2.RESULTS OF A ONE YEAR STUDY (1975) IN THE CITY OF ZURICH

2.1. Age and severity

The mopeddrivers involved in accidents reported by the police were separated in age groups.The incidents of accidents showed a peak at 17 and 18 years (n=13o persons) followed by the group 15 and 16 year old drivers (n=95) (Tab 1).

Seven drivers were killed and 95 severely injured (AIS≥2).The highest degree of traumatisation (cummulated AIS) was found in the category 17 and 18 years (Index =112).Second highest were the 15 and 16 year old group(Index = 67).

The highest average AIS (2,8)was found in the group 71 - 75 year followed by the age group 66- 7o (AIS 1,6) and 61 - 65 (AIS 1,3) and 19 - 2o (AIS 1,3). Scooter drivers over 6o years are rarely involved in accidents because of the small number of drivers at that age but if these people do have an accident the injuries sustained are more often severe than in other age groups.

The target groups of accident prevention should therefore be the scooter drivers between 15 and 2o years and more than 6o years old.

2.2. Risk of different accident situation (Tab 2)

The degree of traumatisation (T) is distributed as follows:

1. Single accidents (T = 77)
2. Accidents as a result of beeing passed by a car or a truck (T = 51)
3. Refusal of giving right of way to cars (T = 35)
4. Disregarding a stop sign (T = 33) and collision with the rear of a car (T = 33)
5. Turning left without signaling (T = 28)

The largst number of accidents with the severity AIS≥2 is consequently due to the faults of the scooter drivers themselves (except situation 2.).

The most traumatic accidents are frontal collisions with oncomming cars (AIS 1,7) followed by collisions with cross traffic (AIS 1,4),single accidents and turning left without signaling (AIS in both cases average 1,3).

The accidents with the most severe consequences are therefore self induced.

2.3. Type of injuries and distribution of body parts involved

Injuries with AIS $\geq$ 2 involved the head in 42 % the thorax in 17 % and the (lower) leg in 14 %.Nearly half of the thorax injuries included fractures of the clavicula (Tab 3).

Head injuries

38 % of all head injuries were sustained by the face including 8 fractures of facial bones.4 % involved teeth fractures.The remaining 58% were other head injuries.Concussion (commotio) is frequent.In 5 of 7 fatalities the cause of death were skull fractures with severe brain damage.
One driver protected with a jethelmet sustained a light concussion only inspite of the severity of the accident.It is assumed that especially the fractures of facial bones could be prevented by a jethelmet.

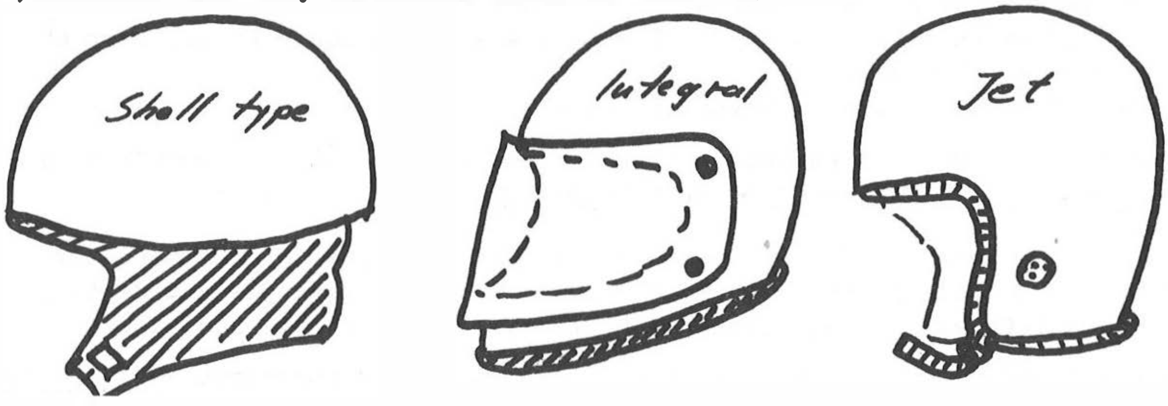
2.4. Causes of death

To render the study more representative with regard to fatal accidents an additional 18 fatalities occurring in Switzerland which were reported to us are included in this study.
The total number of fatalities examined is 25 wereof 17 were due to head injuries,3 to neck fractures, 3 to thorax injuries and 2 to other lesions.
In 13 accidents a car was the collision object, in 7 a truck (5 of them with a trailer).Collisions with heavy goods vehicles are the most dangerous situation for scooter drivers especially because of the risk of beeing overrolled.
In two cases the head was overrun by a truck and in one case the thorax.
Investigations on this problem have been started (Volvo) and should be increased.

3. PROTECTION HELMETS

3.1. Types of helmets

Three types of helmets are distinguished: the simple shell type(light,not expensive) ,the jethelmet (better protection of the ears and the lateral face), the integral helmet (best protection also of the whole face,heavy,rather expensive ,sometimes not easy to remove after an acident).



3.2. Head injuries and protection helmets

As it is done in other publicationes, Hehlen (4) demonstrated that the incidense of head injuries can be dramatically reduced if protection helmets are used. An important point is that not only drivers of fast motorcycles should wear helmets but also drivers of scooters with a top speed of 3o km/h. Langwieder(7), Feldkamp (2), Richardson (12) and Hehlen (4) have found out, that helmets protect slower motorcycles at least at the same extent as fast ones. Often in motorcycle accidents the speed of the collision object is the more important one than the speed of the motorcycle itself.

	persons injured	persons killed	Assumed reduction due to mandatory helmet usage: persons injured	persons killed
Heavy motorcycle	2254	1o6	31/2 %	1o %
Light motorcycle + scooters with more than 5o ccm eng.disp.	1179	37	81/2 %	23 %
Bicycle scooters	4466	156	1o %	25 %
Total	7899	299	1o %	2o %

Calculated reduction of persons injured and killed after a mandatory helmet usage to be expected in Switzerland 1977 or 78 (4). Basis 1974.

3.3. Injuries to helmet protected drivers

Case 1: Helmet simple shell type. The driver tried to overtake a truck on the right side while that vehicle was turning to the right. One wheel overrolled the head "protected" by the weak shell. Death at the scene because of multiple fraktures of the skull and base with severe brain damage.

Case 2: Jethelmet. In a single accident the driver of a heavy motorcycle was thrown onto the road. He sustained fractures of the base. The spinal cord was sheared off due to a total luxatio atlanto-occipitalis. Bleedings in all parts of the cerebral structures. Death at the scene.

Case 3: Integralhelmet. The cyclist ran with his heavy motorcycle into the side of an Audi 8o with a speed of 5o-8o km/h. This thorax was holded back by the side structures of the car and the helmet (1,45 kg) forced the head to swing foreward: Luxatio atlanto-occipitalis with laceration of the cord (no shearing off), bleedings in all parts of the cerebral structures, cerebral edema. The lower frontal margin of the integralhelmet caused a fracture of the clavicula on both sides. The stretching of the chin strap resulted (probabely in the second phase of the accident) in a laceration of the skin and a fracture of the os hyoideum. The chin strap was torn. See Fig.3. Additional injuries: rupture of the vena cava, of the lung, liver and spleen, fracture of the thigh on the right side.

It is seen that helmets can not always prevent fractures of the skull and base. Special attention should be given to indirect injuries to the cerebral mass due to rotational (lo) and translational forces.The injuries sustained hereby are especially bleedings into the subarachnoideal space and in the cerebral mass and an edema of the brain.The brain edema is currantly in severe cases untreateble.

Nevertheless the total number of the injuries of the brain is strongly reduced if a helmet is worn.However injuries to the spine and cord are markedly increased with the wearing of a helmet from 0,8 % without helmet to 5,2 % with helmet (16).To a certain extent this drastic increase is misleading because of the total number of injuries of protected drivers is much smaller (prevention of head injuries).So the injuries to the spine and cord become percentually more important.
However the fear the helmets may increase the number of the injuries to the spine are partly justified.A survey taken among different emergency clinics in Switzerland revealed that little is known about the fact how and where a helmet should be removed after an acident.

4. EXPERIMENTAL INVESTIGATION ON THE BEHAVIOR OF HELMETS UNDER QUASISTATIC AND DYNAMIC LOADING

The overrolling of a head (without or with helmet) is one of the most dangerous accident situation.This problem was therefore examined in an experimental study.
It can not be expected that the stiffness of currently used helmets is such that large deformations are inhibited while beeing overrun.Quasistatic helmet tests with large loads conducted at EMPA (St.Gallen , Switzerland) produced the result shown in Fig.1.

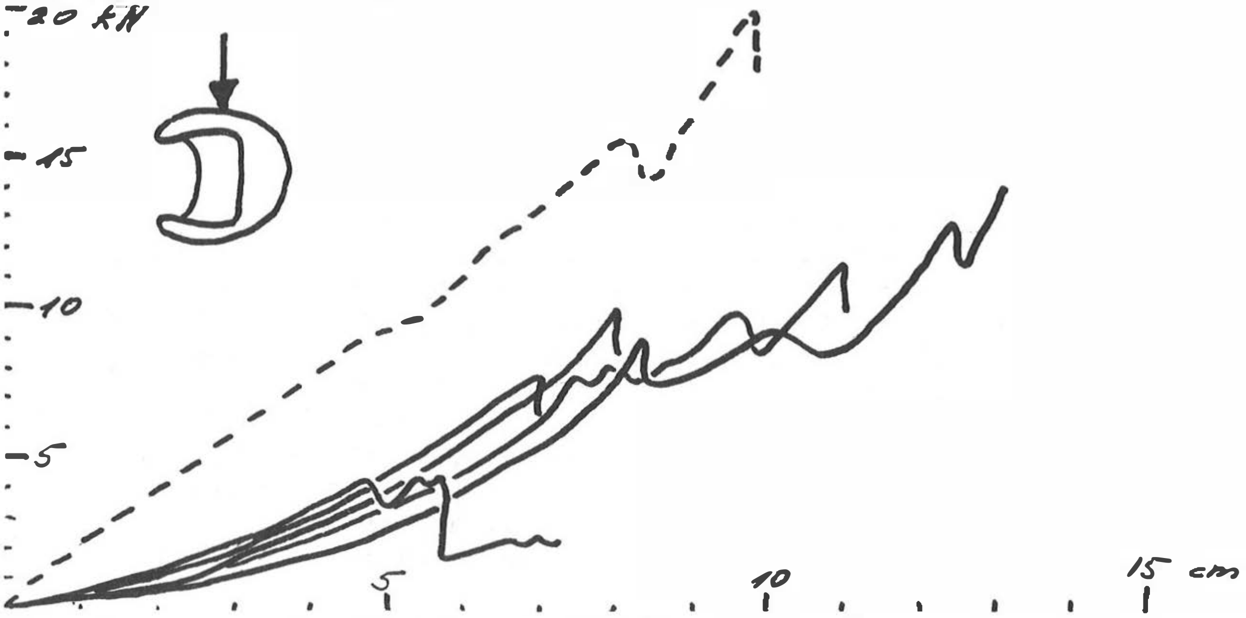


Fig 1. Quasistatic test of integral(---) and jet(——)helmets by EMPA St.Gallen.

It is seen that the integral helmet has a substantially higher stiffness which however is generally not sufficient to give adequate head protection with respect to overrolling since the dynamic load can be expected to be markedly higher than 1/4 of the car weight.

An important question is under what conditions a helmet is beeing pushed away by a wheel rather than overrun. A simplified mechanical analysis of the problem reveales that this is the case if the friction coefficients μ_1 (helmet-ground), μ_2 (helmet-wheel) and the diameter ratio $r = (r_2 - r_1)/(r_2 + r_1)$ satisfied the relation

$$\sqrt{1-r^2}(1-\mu_1\mu_2) - \mu_2 r - \mu_1 > 0 \qquad (1)$$

This follows from the fact that the horizontal force due to R , W ,F has to be directed away from the wheel. This resultant force has in addition to be sufficient large to overcome the inertia forces of the body part pushed away.

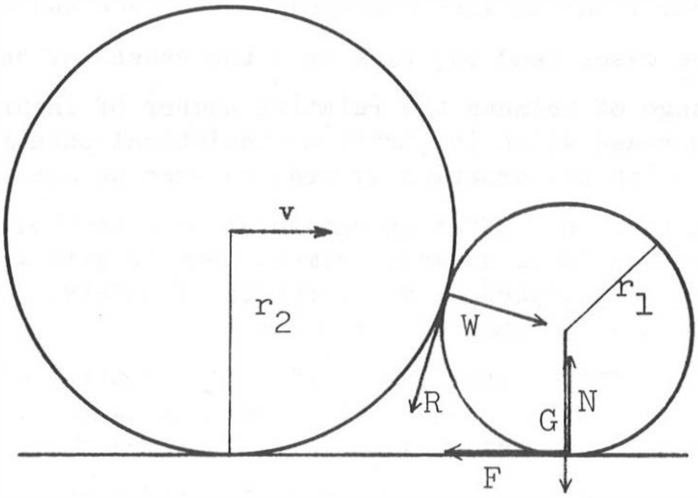


Fig.2 . Simplified model of a wheel (left) impacting a helmet with velocity v

Each combination of μ_1, μ_2, r_1, r_2 satisfying (1) is expected to define a critical speed for overrolling. First experimental results support this hypothesis. A typical example $\mu_1 \sim 0{,}6$, $\mu_2 \sim 0{,}4$, $r \sim 0{,}2$ and the relation is satisfied.

In the situation shown in Fig.4 the head is pushed away with a maximal acceleration of 18 g (vehicle speed = 7 km/h, VW Pick-up). Acceleration see Fig.5.

In contrast to that at 27 km/h the helmet is overrun in Fig. 6 . Thereby the head experiences a maximal acceleration of 40 g (Fig.7).

The relatively high acceleration in the opposite direction after 15 ms is due to the elastic rebound of the head. It can not be decided wether such a response is realistic since we lack sufficient biomechanical data on the neck.

5. CONCLUSIONES

- In Switzerland the lightest category of motorized two wheelers (bicycle scooters,5o ccm,3o km/h,no license,minimum driver age 14 years) show the largest steady increase of injuries among all traffic participants since 1963.They also sustain the greatest number of head injuries.

-The target groups of accidentprevention should be the age group 15 - 2o (many accidents) and that above 6o (particularly severe accidents).

- The largest number of accidents with the severity of AIS≥ 2 and of the accidents with the most severe injuries were selfinduced.

- Injuries of the severity AIS≥2 involved in 42% the head,in 17% the thorax and in 14% the (lower) leg.

- More than 1/3 of all head injuries were conveyed to the face and 4% to the teeth.

- In more than 2/3 of the cases head injuries were the causes of death.

- With a more frequent usage of helmets the relative number of injuries to the spine and cord will increase which is partly a statistical phenomenon because the number of head injuries are drastically reduced when helmets are worn.

- Simple shell type helmets do not offer enough safety due to their lack of protection of ears and lateral face.Integral helmets seem to give the best protection.Jet helmets can be accepted as a compromise of safety,cost,comfort of wearing and ease of removal in case of a head injury.

- Head injuries of drivers with helmets can consist of fractures of skull and base.Bleedings in the brain structures or the subarachnoideal space and an edema of the brain due to the rotational and translational forces are frequent.

- Experimental quasistatic studies show that even the stiffness of an integral helmet does generally not suffice to prevent large deformations during overrolling.This problem does not arise when the helmet is pushed away by the wheel.A suitable choice of helmet diameter and of the friction properties of the exterior surface of the helmet facilitates such a favorable process.

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Tab 1. Age and severity

Age	Cases	Persons with injuries: AIS 1	2	3	4	5	6	Degree of Traumatisation	Average AIS	Persons with inj. AIS ≥ 2
14 and less	13	6	2	-	-	-	-	10	0,77	2
15+16	95	36	10	-	-	1	1	67	0,71	12
17+18	130	53	22	3	-	-	1	112	0,86	26
19+20	32	13	5	4	-	-	1	41	1,28	10
21-25	39	13	8	4	-	-	-	41	1,05	12
26-30	25	15	1	1	-	-	-	20	0,80	2
31-4o	33	18	5	-	-	-	-	28	0,85	5
41-5o	44	22	8	-	1	-	1	48	1,09	10
51-55	14	8	3	-	-	-	-	14	1,00	3
56-60	7	5	1	-	-	-	-	7	1,00	1
61-65	14	7	3	-	-	-	1	19	1,35	4
66-70	8	2	2	1	1	-	-	13	1,62	4
71-75	5	2	1	-	1	-	1	14	2,8o	3
over 75 (87)	1	-	-	-	-	-	1	(6)	(6,0)	1
										95

Tab 2. Risk of different accident situations

Situation	Nrs. of cases	AIS ≥ 2	Average AIS	Degree of traumat.
simple accident	58	22	1,33	77
accident while/after beeing passed	48	10	1,06	51
collision with the rear of a car	44	6	0,73	33
disregarding a stop sign	31	7	1,06	33
refusal of giving right	35	8	1,0	35
turning left without signaling	22	6	1,33	28
collision with cross traffic while turning left	9	4	1,44	13
collision with oncoming cars	6	2	1,67	7

Tab. 3 . <u>Type of injuries and distribution of body parts involved</u>

	Specific "AIS" of every single injury (number)						"AIS"≥2	% of all "AIS"≥2	AIS"≥3	Total
	1	.2	3	4	5	6				
Head	63	37	2	1		5	45	36	8	1o8
Face	61	8					8	6		69
Teeth	7									7
Spine	9					1	2	2	1	11
Arm	19						1	1		2o
Ellbow	16						1	1		17
Forearm	1						3	2		4
Hand	41						4	3		45
Shoulder	18						1	1		19
Thorax	14					1	12	1o	6	26
Clavicula		9					9	7		9
Abdomen	2				2		2	2	2	4
Pelvis	15	2		1			3	2	1	18
Thigh	16	2	1				3	2	1	19
Knie	58	5	2				7	6	2	65
Leg	54	12	4	1			17	14	5	71
Malleolus	25	5	2				7	6	2	32
Foot	17	1					1	1		18
Unknown	22									22
Total	458	98	16	3	2	7	125	1oo %	28	584

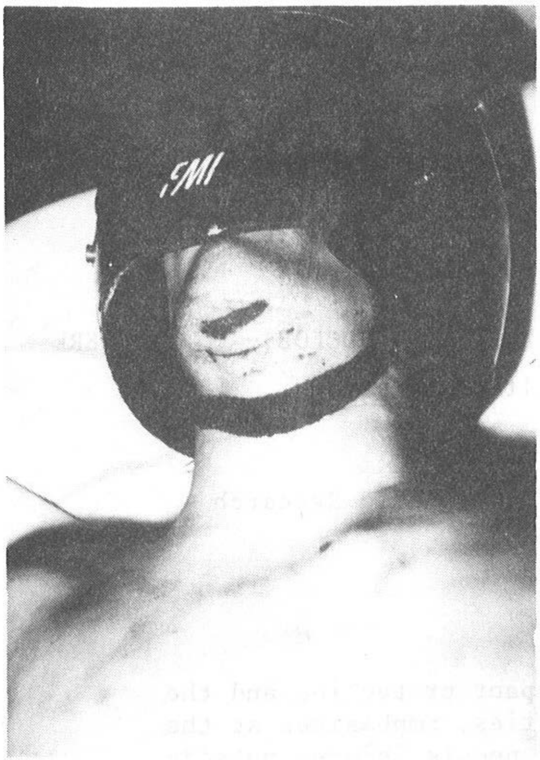

Fig.3.Laceration of the skin due to chin strap.(Case 3).

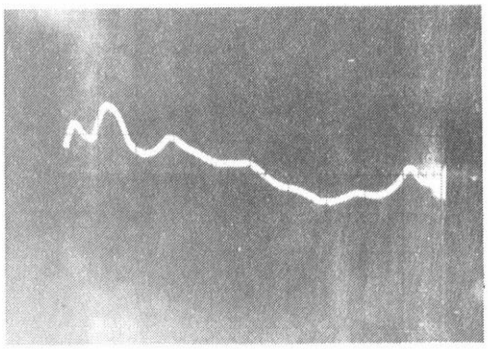

Fig.5. Max.acceleration 18g at loms

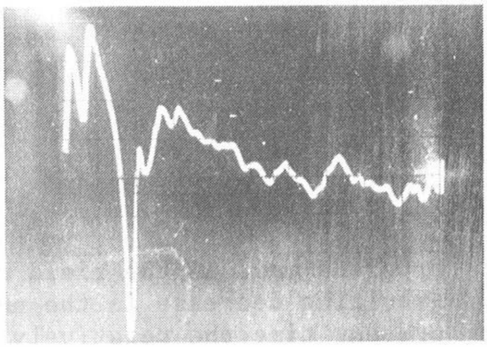

Fig.7.Max.acceleration 4og atloms

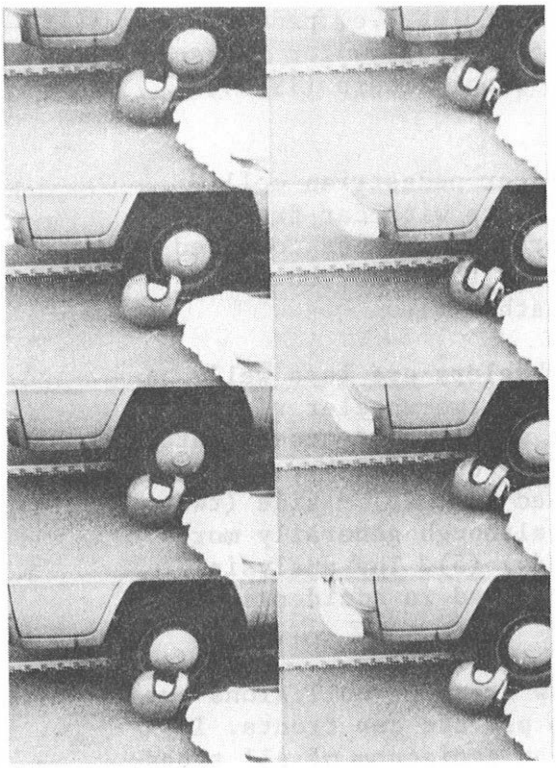

Fig.4.The helmet is pushed away (7km/h)

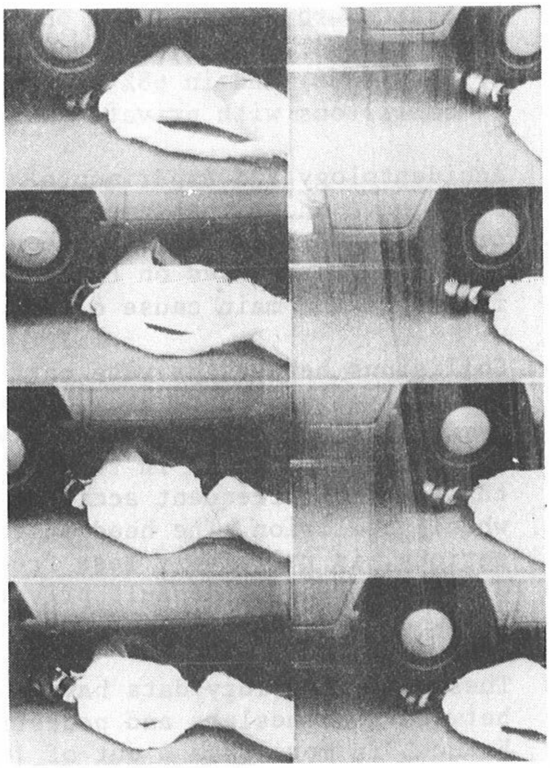

Fig.6.The helmet is overrolled(27km/h)