A I R R E S T I S T A N C E O F C R A S H H E L M E T S

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Summary.

Air resistance of crash helmets with visors opened and closed was measured as well as the antagonizing muscular force. The angle of inclination of the opened visor seemed to be an important parameter. Up to 15% of the males and 64% of the females cannot match air resistance forces.

Introductory remarks.

In most countries it is compulsory for motorcyclists to wear crash helmets which at first were combined with goggles. Later loose visors came in general use. At present visors are often directly attached to the helmet. Pivots allow the visor to be turned up in case the visor is soiled.
In order to prevent the air flow from closing it suddenly the visor must be opened far enough because the air flow should keep the visor opened. Sudden closing of the visor is prevented by choosing a more vertical position of the opened visor, so that the air flow will keep it opened. However a more vertical visor position entails a greater air resistance force. It is open to question whether motorcyclists are capable to prevent the falling backwards of their heads at high speed driving with opened visor. In general it is considered that the falling backwards of the head may cause a dangerous situation. Motorcyclists meet even greater dangers when they use one hand pushing the visor through the critical angle of inclination which causes the visor to strike the helmet because of the sudden increase of air resistance. There are many important factors e.g. reaction time, attention, traffic conditions, etc, however because of the complexity of these dynamic factors the investigation was restricted to static factors only. The air resistance forces on the helmets and the antagonizing muscular forces were assessed.

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INVESTIGATIONS.

I. Air resistance forces on the helmets.

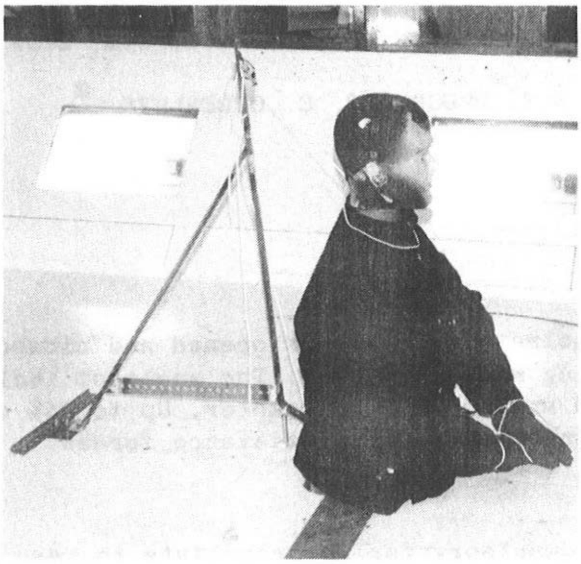

Fig. 1.

Figure 1 shows a 50^{th} percentile TNO 10 manikin placed in a windtunnel. The head is mounted on a rod with a strain gauge force transducer. Air resistance forces are measured and the transducer is calibrated to measure a resulting horizontal force pointing through the forehead just above the eyebrows. The amplified strain gauge signal is recorded by means of an ultra-violet recorder.

Helmet sample	Visor surface (cm^2)	Rotation angle (^{o})
1	340	50
2	460	60
3	460	100
4	600	135

Table 1.

Details of the helmets.

The rotation angle is defined as the angle between closed and totally opened visor position.

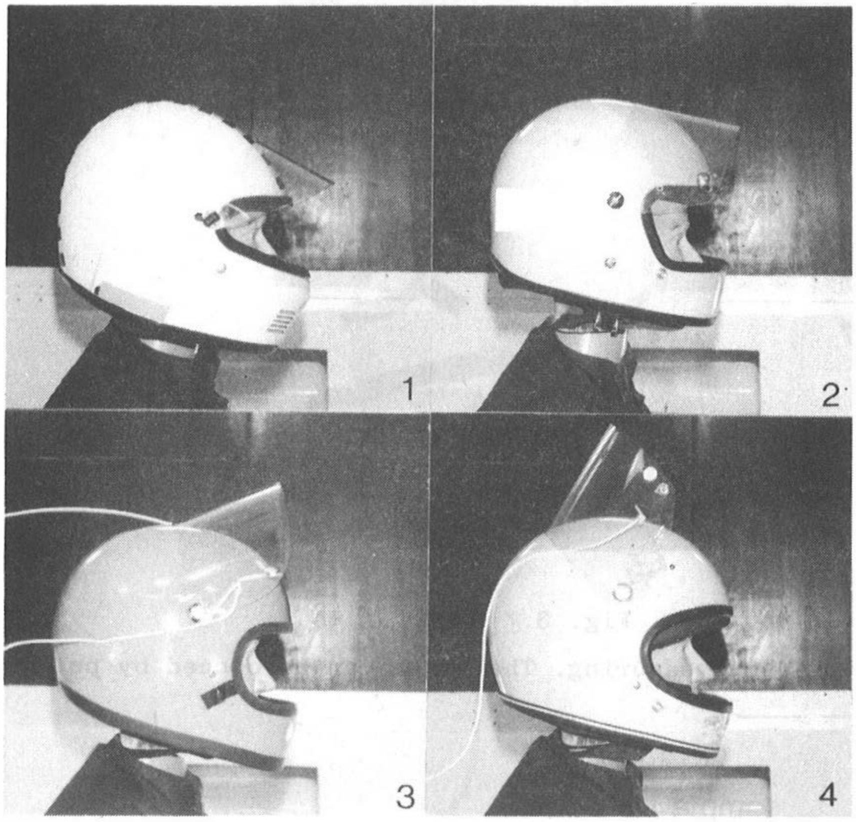

Fig. 2.

Pictures of four helmets of equal size.

Tests:

1. Air resistance measurement with closed visor at speeds of 0 to 40 m/s.
2. Air resistance measurement with opened visor at speeds of 0 to 40 m/s.
3. Measurement of peak force when the visor is opened at 30 m/s.

Helmet sample	Closed visor		Opened visor		Peak force
	30 m/s	40 m/s	30 m/s	40 m/s	30 m/s
1	23,1	31,4	40,6	56,1	- - -
2	30,4	39,6	51,6	82,5	82,5
3	23,1	29,7	77,6	112,2	102,3
4	23,1	31,4	110,6	155,1	160,0

Table 2.

Table 2 presents the air resistance in N at speeds of 30 and 40 m/s.

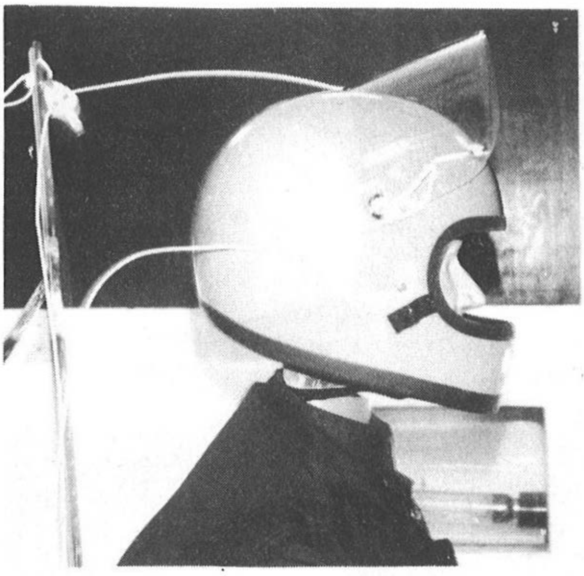

Fig. 3.

Figure 3 shows the method of measuring. The visor can be opened by pulling a string.

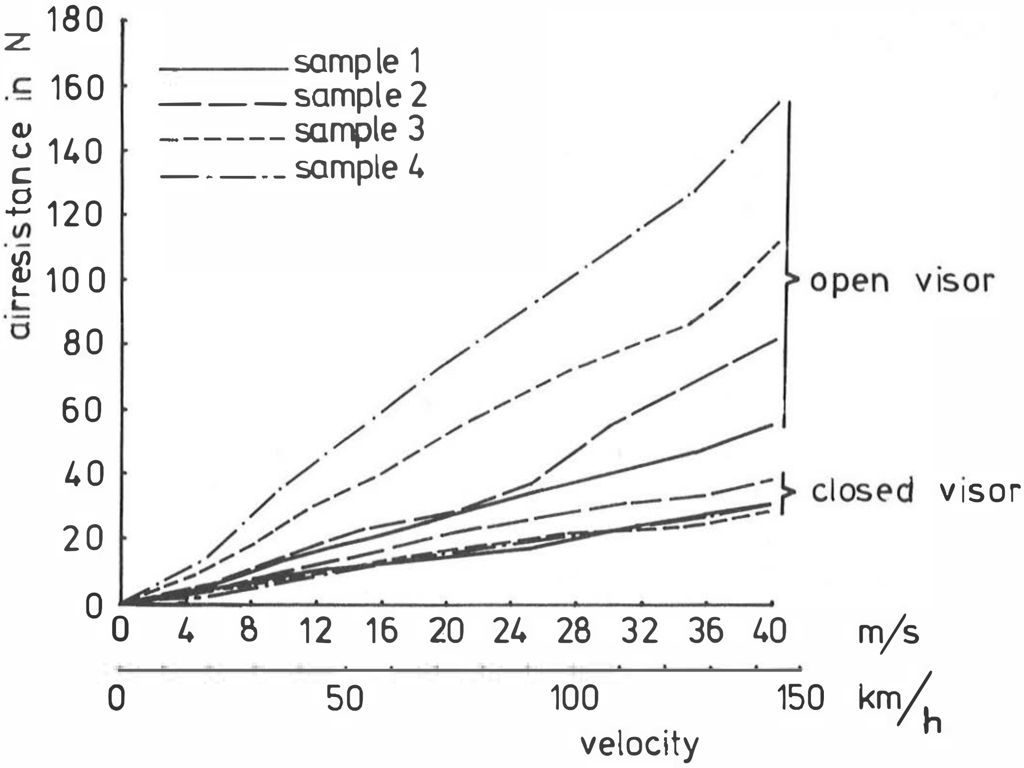

Fig. 4.

Air resistance versus velocity between 0 and 40 m/s.

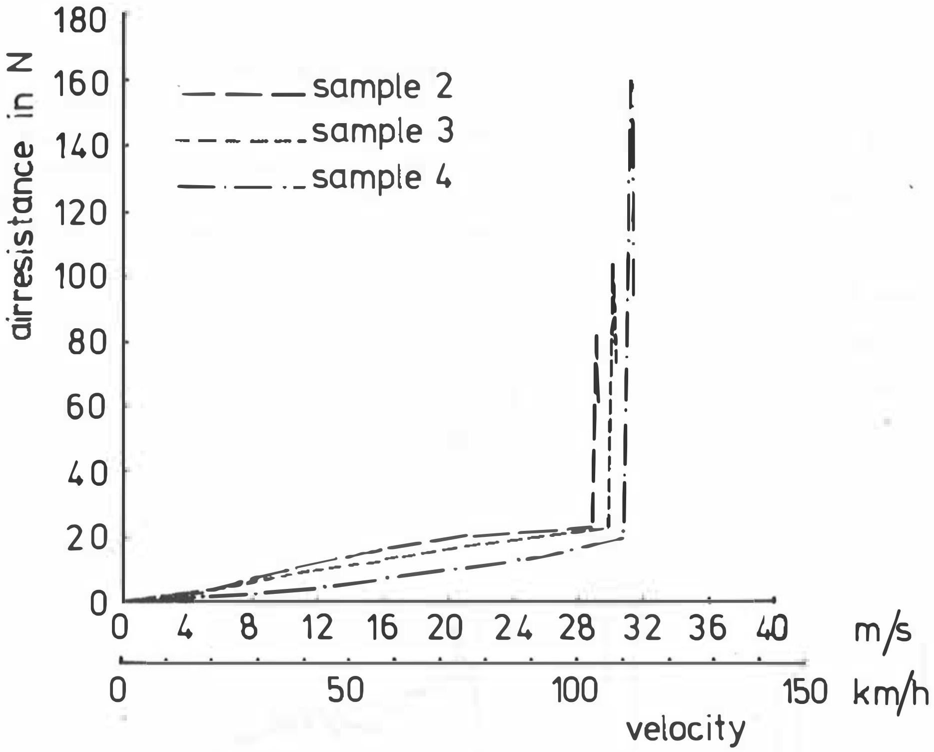

Fig. 5.

Figure 5 shows the peak force resulting from opening the visor at a speed of 30 m/s. Peak force was not measured in sample 1, but because of the other findings of this helmet its peak force is expected to be low.

II. The antagonizing muscular forces.

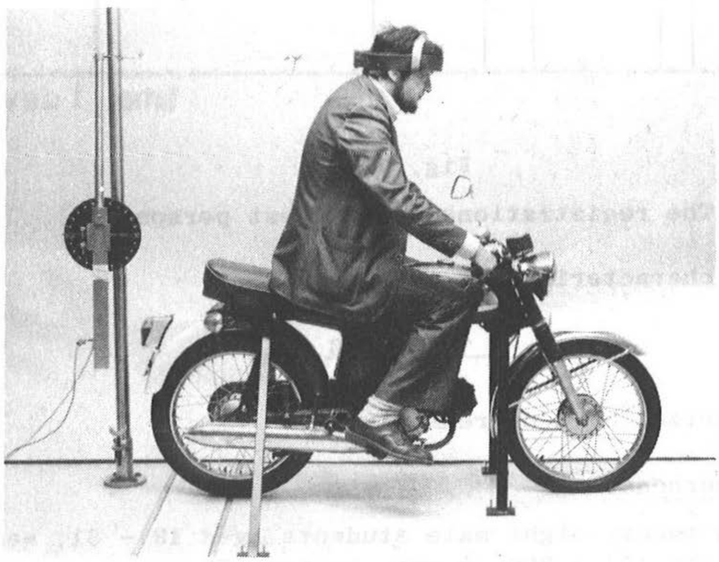

Fig. 6.

Illustration of method.

A person mounts a motorcycle as it occurs during real driving. A belt is positioned around the forehead just above the eyebrows and is connected by means of a string to a force transducer which can be adjusted in height so that the string is kept horizontally. The signal is amplified, recorded and digitalized by means of an analogue-digital converter. Pictures were taken with a fixed camera during muscular effort in order to check the position of the body.

Three conditions had to be fullfilled by each person:

1. A short maximal anteflecting force.
2. A short maximal anteflecting force a minute later.
3. A maximal anteflecting force at least 10 seconds.

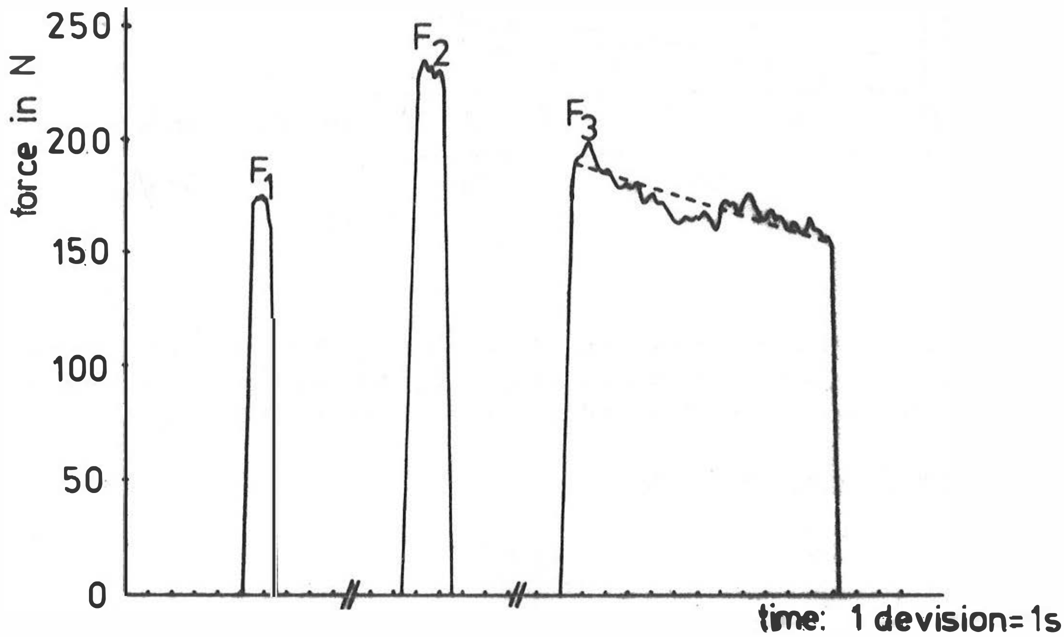

Fig. 7.

The registrations of one test person.

The test person is characterized by the mean:

$$\bar{F} = \frac{F_1 + F_2 + F_3}{3}$$

Fatigue is characterized by a decrease in F_3.

<u>The group of test persons.</u>

Fourteen female and twenty-eight male students aged 19 - 31, weighing 60 - 104 kg and height 154 - 200 cm were tested. The variability of the measurements has been assessed by testing one person twelve times at different hours of a day. By approximation a standard deviation of 15% was found which is acceptable for biomechanical testing.

Mean values are given in table 3 and 4. Subdivisions in age, weight and height were only applied in the male group.

age	20 - 31 year
weight	48 - 77 kg
height	154 - 180 cm
$\bar{F}$	144 N
standard deviation	35 N

Table 3.

Females.

age	19 - 20 year	21 - 24 year	25 - 29 year	19 - 30 year
number	10	10	8	28
$\bar{F}$	207 N	234 N	233 N	222 N
standard deviation	45 N	104 N	84 N	71 N
weight	60 - 69 kg	70 - 79 kg	80 - 104 kg	
number	11	11	6	
$\bar{F}$	182 N	242 N	270 N	
standard deviation	45 N	80 N	80 N	
height	$<$ 180 cm	$\geq$ 180 cm		
number	10	18		
$\bar{F}$	187 N	243 N		
standard deviation	58 N	77 N		

Table 4.

Males.

The decrease of F_3 during 10 sec was assessed in each person. For the whole group a mean decrease of $(1,5 \pm 0,6)$ %/s was found. Based on the $\bar{F}$ and the standard deviation a summated Gauss-curve was constructed which gives the anteflecting muscular force versus the percentage of persons capable of producing this force.

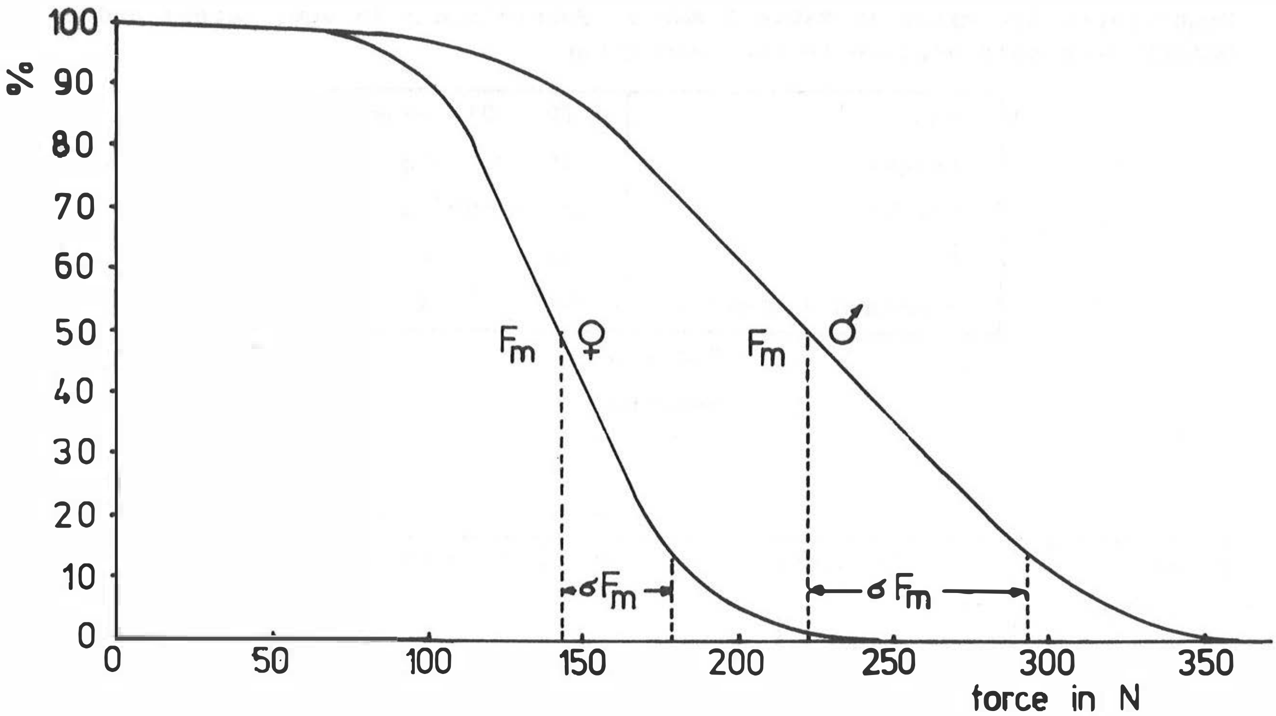

Fig. 8.

Relation between force and percentage of persons.

Conclusive remarks.

A percentage of persons is not able to produce a force large enough to prevent the head falling backwards when the visor is turned up at a certain speed. The findings of the windtunnel measurements and figure 8 are used to arrive at a percentage representing those whose head will fall backwards.

	M A L E S				F E M A L E S			
	30 m/s		40 m/s		30 m/s		40 m/s	
helmet sample	closed %	opened %	closed %	opened %	closed %	opened %	closed %	opened %
1	1,0	1,0	1,0	1,5	1,0	1,0	1,0	1,5
2	1,0	2,0	1,0	2,5	1,0	2,0	1,0	4,0
3	1,0	2,5	1,0	5,0	1,0	2,5	1,0	17,5
4	1,0	5,0	1,0	15,0	1,0	14,0	1,0	64,0

Table 5.

Percentage of persons with muscular force less than the air resistance force.

Table 5 shows that up to 15% of the males and 64% of the females cannot match the air resistance forces. Because only static measurements were made even persons who can supersede the air resistance forces may be at risk when using these visors.

CONCLUSIONS:

- The opening of certain visors at a high speed is highly dangerous.
- The opening of certain visors at a lower speed is hazardous to certain groups and certainly discomfortly because the strain on the neck muscles.
- Dangers can be decreased by eliminating the visor which can be turned up and by developing an other system for removing the soiled visor. The opening of the visor should not disturb the aerodynamics of the helmet and this may be achieved by choosing a better position of the pivots of the visor or by using a sash window-system.