



Bicycle Helmets
2017
tested by Folksam

Folksam

This is why we test bicycle helmets

Every day three cyclists in Sweden sustain head injuries, which are some of the most severe injuries a cyclist can experience. Data from real-life crashes show that bicycle helmets are very effective to reduce injuries. Two out of three head injuries from bicycle accidents could have been avoided if the cyclist had worn a helmet.

We are committed to what is important to our customers and to you. When we test and recommend safe bicycle helmets we believe this can help to make your life safer and we provide tips on how to prevent injury.

How does a bicycle helmet obtain our good choice label?

Helmets which obtain the best overall results in the bicycle helmet test by Folksam are given our good choice label. The good choice symbol may only be used by products which have obtained the best scores in one of our tests.



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Summary

Folksam has tested eleven bicycle helmets on the Swedish market for teenagers and adults. All helmets included in the test have previously been tested and approved according to the CE standard, which means that the energy absorption of the helmets has been tested with a perpendicular impact to the helmet. This does not fully reflect the scenario in a bicycle crash. In a single-bicycle crash or in collision with a motor vehicle, the impact to the head will be oblique towards the ground or the car. The intention was to simulate this in the tests since it is known that angular acceleration is the dominating cause of brain injuries. The objective of this test was to evaluate helmets sold on the Swedish market. Four physical tests were conducted, shock absorption with straight perpendicular impact and three oblique impact tests. Computer simulations were made to evaluate injury risk.

All helmets except four showed a linear acceleration lower than 180 g, which corresponds to a low risk of skull fracture. The simulations indicated that the strain in the grey matter of the brain during oblique impacts varied between helmets from 13% to 36%, where 26% corresponds to 50% risk for a concussion. Helmets equipped with Multi-directional Impact Protection System (MIPS) performed in general better than the others. However, all helmets need to reduce rotational acceleration more effectively. A helmet that meets the current standards does not necessarily prevent concussion. In total four helmets obtained the Folksam good choice label: Bell Event XC MIPS, Bell Super 3 MIPS, Occano U MIPS Inmold HLM and Specialized S-Works Prevail II. All except Specialized S-Works Prevail II are fitted with MIPS (Multi-directional Impact Protection System) with the intention to reduce the rotational energy.

The current European certification test standard do not cover the helmets' capacity to reduce the rotational acceleration, i.e., when the head is exposed to rotation due to the impact. The present study provides evidence of the relevance of including rotational acceleration in consumer tests and legal requirements. The results have shown that rotational acceleration after impact varies widely among helmets in the Swedish market. They also indicate that there is a link between rotational energy and strain in the grey matter of the brain. In the future, legal bicycle helmet requirements should therefore ensure a good performance for rotational forces as well. Before this happens, consumer tests play an important role in informing and guiding consumers in their choice of helmets. The initial objective of the helmet standards was to prevent life threatening injuries but with the knowledge of today a helmet should preferably also prevent brain injuries resulting in long-term consequences. Helmets should be designed to reduce the translational acceleration as well as rotational energy. A conventional helmet that meets current standards does not prevent a cyclist from getting a concussion in case of a head impact. Helmets need to absorb energy more effectively.

Method

In total, 11 conventional helmets were selected from the Swedish market. To ensure that a commonly used representative sample was chosen, the range helmets available in bicycle/sports shops and in online shops were all considered. The test set-up used in the present study corresponds to a proposal from the CEN Working Group's 11 "Rotational test methods" (Willinger et al. 2014). In total, four separate tests were conducted (Table 1). A finite element (FE) model of the brain was used to estimate the risk of brain tissue damage during the three oblique impact tests.

Table 1. INCLUDED TESTS

TEST	VELOCITY	ANGLE	DESCRIPTION
Shock absorption test	5.6 m/s	0°	The helmet was dropped from a height of 1.5 m to a horizontal surface correlated to the regulation EN 1078.
Oblique impact A. Contact point on the upper part of the helmet.	6.0 m/s	45°	A test that simulates an actual cyclist-vehicle-crash or a single bicycle crash. Rotation around X-axis.
Oblique impact B. Contact point on the side of the helmet.	6.0 m/s	45°	A test that simulates an actual cyclist-vehicle-crash or a single bicycle crash. Rotation around Y-axis.
Oblique impact C. Contact point on the frontal side of the helmet.	6.0 m/s	45°	A test that simulates an actual cyclist-vehicle-crash or a single bicycle crash. Rotation around Z-axis.
Computer simulations	-	-	As input into the FE model, the measured rotational and translational accelerations from the HIII head in the three tests above were used.

Shock absorption test

The helmet was dropped from a height of 1.5 m to a horizontal surface according to the European standard which sets a maximum acceleration of 250 g (EN1078 2012) (Fig. 1). The shock absorption test is included in the test standard for helmets (EN 1078), in contrast to the oblique tests. The ISO head form was used and the test was performed with an impact speed of 5.42m/s. The helmets were tested in a temperature of 18°C.

The test was performed by Research Institutes of Sweden (RISE) which is accredited for testing and certification in accordance with the bicycle helmet standard EN 1078.



Figure 1. The method used in shock absorption test.

Oblique Tests

In three oblique tests the ISO headform was replaced by the Hybrid III 50th percentile Male Dummy head. The reason for this choice was that the Hybrid III 50th percentile male dummy head has much more realistic inertia properties and it allows for measurements of the linear and rotational velocity

and acceleration. A system of nine accelerometers was mounted inside the Hybrid III test head according to the 3-2-2-2 method described by Padgaonkar et al. (Padgaonkar et al. 1975). Using this method it is possible to measure the linear accelerations in all directions and the rotational accelerations around all the three axis X, Y and Z. The accelerometer samples were obtained at a frequency of 20 kHz and all the collected data were filtered using an IOtechDBK4 12-pole Butterworth low-pass filter. This is further described by Aare and Halldin (2003). The helmeted head was dropped against a 45° inclined anvil with friction similar to asphalt (grinding paper Bosch quality 40). The impact speed was 6.0m/s. The Hybrid III dummy head was used without an attached neck. Two helmets were tested in each test configuration to minimize variations.



Figure 2. The oblique test A with rotation around X-axis.



Figure 3. The oblique test B with rotation around Y-axis.



Figure 4. The oblique test C with rotation around Z-axis

FE Model of the brain – Computer simulations

Computer simulations were carried out for all oblique impact tests. The simulations were conducted by KTH (Royal Institute of Technology) in Stockholm, Sweden, using an FE model that has been validated against cadaver experiments (Kleiven and Hardy 2002; Kleiven 2006) and against real-world accidents (Kleiven 2007; Patton et al. 2013). It has been shown that a strain above 26% corresponds to a 50% risk for concussion (Kleiven and Hardy 2002). As input into the FE model, X, Y and Z rotation and translational acceleration data from the HIII head were used. The FE model of the brain used in the tests is described by Kleiven (Kleiven 2006; Kleiven 2007).

Results

All helmets scored lower than 250 g in resultant acceleration in the shock absorption test (Table 2). The Specialized S-Works Prevail II (131 g) performed best of the helmets, and B'TWIN MTB 500 (191 g) performed worst of the helmets.

Table 2. SHOCK ABSORPTION - LINEAR ACCELERATION

Helmet	Translationsacceleration (g)
ABUS Urban-I 2.0	187
Bell Event XC MIPS	155
Bell Super 3 MIPS	141
Bern Brentwood	184
B'TWIN MTB 500	191
GIRO Trinity MIPS	177
Occano U MIPS Inmold HLM	152
Specialized Ambush	141
Specialized S-Works Prevail II	131
Spectra Urbana EV1 MIPS	183
TEC Umbra EV1 MIPS	177
Mean/Median	165/ 177

Table III shows the tests that reflect the helmet's protective performance in a bicycle crash with oblique impact to the head (rotation around the X-axis, Y-axis and Z-axis). The mean value of the rotational accelerations varied between the three tests and the lowest strain was measured in the oblique test with an impact to the side of the helmet (rotation around X-axis). The simulations indicated that the strain in the grey matter of the brain during oblique impacts could vary between helmets, from 13% to 28% in the test with rotation around X-axis, 25% to 36% in rotation around Y-axis and 21% to 32% in rotation around Z-axis. The threshold for 50% risk of concussion was only exceeded by one helmet (Bern Brenwood) when the impact caused a rotation around the X-axis. Only two helmet did not give results that exceeded the threshold for a 50% risk of concussion during the impact with rotation around Y-axis. When impacting the frontal part of the helmet (rotation around the Z-axis) the threshold was exceeded in five of eleven tests. Helmets equipped with MIPS performed, in general, better than the others. The strain in the brain model was 13-37% lower for helmets fitted with MIPS.

Table 3. OBLIQUE TESTS (ROTATION AROUND THE X, Y AND Z-AXIS)

Helmet	OBLIQUE IMPACT A (X-AXIS)					OBLIQUE IMPACT B (Y-AXIS)					OBLIQUE IMPACT C (Z-AXIS)				
	T. ACC. [g]	R. ACC. [krad /s ²]	R. V [rad/s]	BrIC	Strain [%]	T. ACC. [g]	R. ACC. [krad/s ²]	R. V [rad/s]	BrIC	Strain [%]	T. ACC. [g]	R. ACC. [krad/s ²]	R. V [rad/s]	BrIC	Strain [%]
Abus Urban-I 2.0	136.4	9.42	33.5	0.96	25.2	131.6	8.88	37.6	1.03	35.5	120.2	7.12	28.3	0.79	29.0
Bell Event XC MIPS	102.6	5.11	21.3	0.59	14.1	107.4	4.92	27.9	0.73	24.5	101.7	5.69	25.3	0.69	25.3
Bell Super 3 MIPS	102.9	4.90	24.3	0.65	17.1	96.8	5.42	32.2	0.83	25.1	92.2	4.58	23.2	0.62	20.7
Bern Brentwood	138.8	10.02	34.0	0.99	28.3	135.1	8.70	39.2	1.06	34.3	133.4	8.17	29.5	0.84	31.4
B'TWIN MTB 500	138.1	9.74	24.6	0.78	21.3	143.5	8.42	34.9	0.96	33.5	133.9	8.20	31.9	0.89	31.7
Giro Trinity MIPS	111.1	4.50	21.5	0.58	17.7	134.7	7.13	27.6	0.77	31.4	113.6	5.76	28.1	0.75	28.2
Occano U Mips Inmold HLM	120.5	6.49	24.7	0.70	16.2	121.0	6.35	34.5	0.90	26.9	107.4	5.89	27.5	0.74	24.0
Specialized Ambush	119.7	8.00	28.5	0.82	20.9	109.8	6.60	34.8	0.92	27.9	103.0	6.84	29.9	0.82	27.5
Specialized S-Works Prevail II	113.0	8.25	30.7	0.87	18.5	85.0	5.37	35.8	0.91	27.6	87.8	4.92	28.8	0.74	24.2
Spectra Urbana Ev1 MIPS	120.6	4.69	17.2	0.49	13.2	130.4	7.16	24.5	0.71	30.0	127.1	5.32	20.2	0.57	25.8
Tec Umbra Ev1 MIPS	113.8	6.44	25.3	0.64	21.7	130.3	7.73	29.4	0.83	30.9	111.8	5.78	20.8	0.59	24.7
Medel	119.8	7.05	26.0	0.73	19.5	120.5	6.97	32.6	0.88	29.8	112.0	6.21	26.7	0.73	26.6
Median	119.7	6.49	24.7	0.70	18.5	130.3	7.13	34.5	0.90	30.0	111.8	5.78	28.1	0.74	25.8

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