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2019

Bicycle Helmets 2019
Tested by Folksam

S40150 19-06

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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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Why is Folksam testing bicycle helmets?
Approximately three cyclist sustain a head injury after a fall or a crash every day in Sweden (Stigson 2015). In total 70 percent of the head injuries occur in a single bicycle crash. Even though less than a fifth of the head injuries occur when a passenger car was involved, these often result in the most severe injuries. The risk of sustaining a head injury is mitigated if cyclists are using helmets. This has been demonstrated by epidemiological studies showing that bicycle helmets can reduce head injury risk by up to 69%(Olivier and Creighton 2016). All helmets included in the test are 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 (EN1078 2012). This does not fully reflect the scenario in a bike accident. In a fall or a crash, the impact to the head will be oblique (Willinger et al. 2014; Fahlstedt 2015; Bland et al. 2018). The intention was to simulate this in the test 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 for teenagers and adults. In total Folksam has tested 12 bicycle helmets, Table 1.

***Table 1**. Included helmets*

Bike helmets	Rotational technologies	Price (SEK)
6D ATB-1T EVO	ODS[1]	1600
Abus Pedelec 2.0	-	1500
Bontrager Charge WaveCel	WaveCel	1700
Giro Aether MIPS	MIPS Spherical[2]	2300
Giro Syntax MIPS	MIPS[3]	1100
Lazer Gustav MIPS	MIPS	1000
Oakley ARO3 MIPS	MIPS	1500
Occano Sport Helmet	-	300
Oxford Hurricane F15	-	200
POC Omne Air SPIN	SPIN[4]	1600
Specialized Propero 3 Angi Mips	MIPS	1500
Tec Nice	MIPS	900

[1] Omni-Directional Suspension
[2] Multi-directional Impact System Spherical
[3] Multi-directional Impact System
[4] Shearing Pad Inside

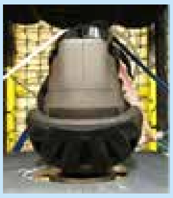
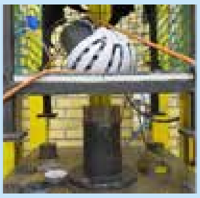
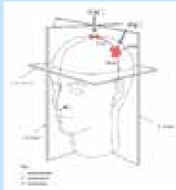
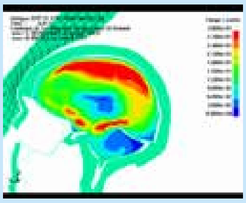
Method
Five physical tests were conducted, two shock absorption tests with straight perpendicular impact and three oblique impact tests (Table 2). Computer simulations were made to evaluate injury risk.

Shock Absorption Test
The helmet was dropped from a height of 1.5 m to a horizontal surface according to the European standard (EN1078 2012) which sets a maximum acceleration of 250 g. The shock absorption test is included in the test standard for helmets, in contrast to the oblique tests. The test was performed by Research Institutes of Sweden (RISE) which is accredited for testing and certification in accordance with the European standard.

Oblique Tests
The helmeted head was dropped against a 45° inclined anvil with friction similar to asphalt (grinding paper Bosch quality 40). The impact speed was 6.25m/s. The Hybrid III dummy head was used without an attached neck. Two helmets were tested in each test configuration to minimize variations. 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). The test was performed by Research Institutes of Sweden (RISE).

Computer Simulations with FE Model of the Brain
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 experimental testing were used. The FE model of the brain used in the tests is described by Kleiven (Kleiven 2006; Kleiven 2007).

Table 2. Included tests

Included test	
Shock Absorption Test (EN 1078) *The helmet was dropped from a height of 1.5 m to a horizontal surface correlated to the European Standard EN1077 test protocol. The ISO head form was used, and the helmets were tested in a temperature of 18°C. The head was impacted at two different locations. One at the top of the head and one at the side of the head, see figure. Velocity 4.7 m/s*	  
Oblique Impact – Rotation around X-axis *Contact point on the side of the helmet resulting in a rotation around X-axis. Initial position of the headform X-, Y- and Z-axis 0° Hybrid III 50th percentile Male Dummy head form was used. Velocity 6.3 m/s*	
Oblique Impact – Rotation around Y-axis *Contact point on the upper part of the helmet resulting in a rotation around Y-axis. Initial position of the headform X-, Y- and Z-axis 0° Hybrid III 50th percentile Male Dummy head form was used. Velocity 6.3 m/s*	
Oblique Impact – Rotation around Z-axis *Contact point on the upper part of the helmet resulting in a rotation around Y-axis. Initial position of the headform X- and Z-axis 0° and 65° around Y-axis. Hybrid III 50th percentile Male Dummy head form was used. Velocity 6.3 m/s*	
Computer Simulations *Computer simulations were carried out for all oblique impact tests. As input into the FE model, the measured rotational and translational accelerations from the HIII head in the three tests above were used. A strain above 26% corresponds to a 50% risk for concussion.*	

Rating of Helmets

The safety level of the helmets was rated relative to each other. Since the most common brain injuries often occur in oblique impacts the three oblique tests were influencing the rating to a higher extend. The overall result was calculated according to the equation below where T1 and T2 are the relative result in shock absorption and T3-5 are the relative results in the oblique impact tests.

$$\frac{\frac{T_1 + T_2}{2} + \frac{2 * (T_3 + T_4 + T_5)}{3}}{3}$$

Results

In total three helmets obtained the Folksam good choice label: Giro Aether MIPS, Specialized Propero 3 Angi MIPS and Tec Nice, Table 3. These helmets performed up to 36% better than the average helmet. All three helmets are fitted with MIPS (Multi-directional Impact Protection System) with the intention to reduce the rotational energy.

Table 3. *Overall results*

Helmet	Overall result	Folksam's label
6D ATB-1T EVO	-21%	
Abus Pedelec 2.0	-3%	
Bontrager Charge WaveCel	2%	
Giro Aether MIPS	19%	Good Choice
Giro Syntax MIPS	-1%	
Lazer Gustav MIPS	10%	
Oakley ARO3 MIPS	7%	
Occano Sport Helmet	-27%	
Oxford Hurricane F15	-36%	
POC Omne Air SPIN	-9%	
Specialized Propero 3 Angi Mips	21%	Good Choice
Tec Nice	36%	Good Choice

All helmets scored lower than 250 g in resultant acceleration in the shock absorption test (Figure 1). The lowest values were measured for Abus Pedelec 2.0 and Giro Aether MIPS (157g).

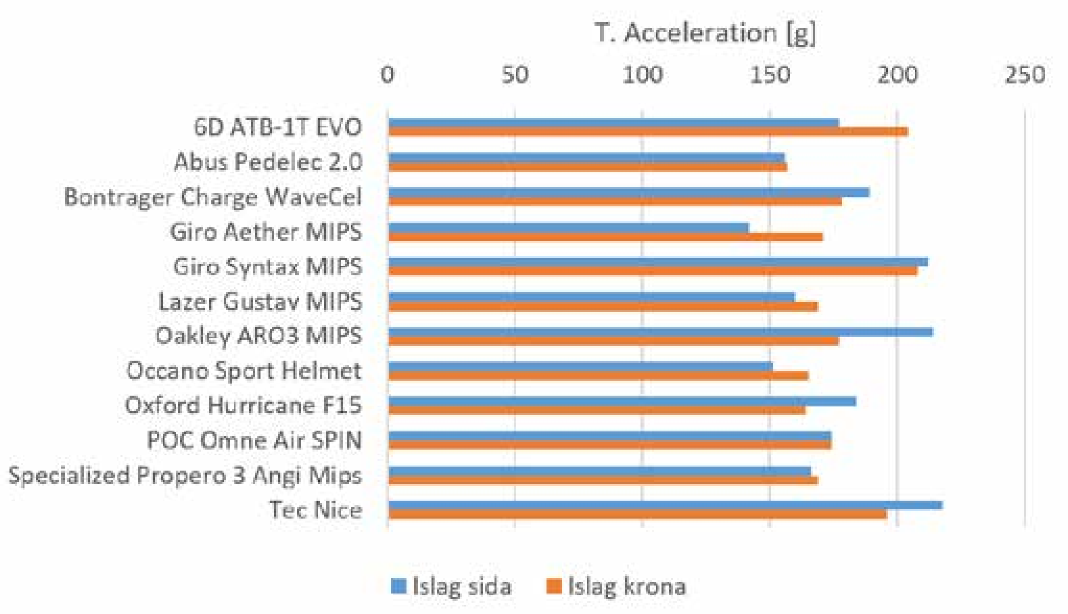


Figure 1. *Shock Absorption measuring linear acceleration*

Table 4 shows the tests that reflect the helmet's protective performance in a bike accident with oblique impact to the head (rotation around the X-axis, Y-axis and Z-axis). The simulations indicated that the strain in the grey matter of the brain during oblique impacts could vary between helmets, from 8% to 38%. In total five helmets got a result that was below the threshold for a 50% risk of concussion in all the three tests. In general, helmets equipped with MIPS performed better than the others.

Discussion

The current European certification test standard does 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 on 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 helmet requirements should therefore ensure a good performance for rotational loading as well. Before this happens, consumer tests play an important role in informing and guiding consumers in their choice of helmets. Since 2012 Folksam have conducted nine consumer helmet tests (seven bicycle helmet tests, two equestrian helmet tests and two ski helmet tests). During this time the proportion of helmets fitted with additional new technologies aimed to reduce rotational acceleration have been more common. In the present test nine out of twelve had some of these technologies. In general, helmets equipped with MIPS performed better than the others. However, all helmets need to reduce rotational acceleration more effectively. 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. Therefore, helmets should be designed to reduce the translational acceleration as well as rotational acceleration. A conventional helmet that meets current standards does not prevent a cyclist from sustaining a concussion in case of a head impact. Helmets need to absorb energy more effectively.

Table 4. Oblique Tests (Rotation Around The X, Y And Z-Axis)

	Oblique Impact A (X-Axis)					Oblique Impact B (Y-Axis)					Oblique Impact C (Z-Axis)				
Bicycle helmet	T. ACC. [g]	R. ACC. [krad / s2]	R. V [rad/s]	BrIC	Strain/Risk of concussion [%]	T. ACC. [g]	R. ACC. [krad / s2]	R. V [rad/s]	BrIC	Strain/Risk of concussion [%]	T. ACC. [g]	R. ACC. [krad / s2]	R. V [rad/s]	BrIC	Strain/Risk of concussion [%]
6D ATB-1T EVO	153,3	9,1	36,5	0,21	25/44	136,7	7,1	35,4	0,66	27/50	131,0	8,5	34,5	0,15	29/56
Abus Pedelec 2.0	125,8	8,9	35,3	0,14	25/43	124,4	7,1	35,9	0,67	28/53	106,2	7,0	26,4	0,08	20/29
Bontrager Charge WaveCel	119,3	6,5	27,7	0,25	20/29	122,6	5,1	30,0	0,56	19/27	116,4	7,4	38,1	0,12	29/58
Giro Aether MIPS	110,6	3,4	23,0	0,08	11/11	128,6	4,8	29,1	0,54	20/28	146,8	8,7	38,3	0,25	29/58
Giro Syntax MIPS	125,9	8,5	25,6	0,21	19/26	151,2	6,2	32,0	0,60	24/40	136,5	7,4	30,0	0,07	25/44
Lazer Gustav MIPS	130,7	7,0	30,2	0,20	21/32	112,3	4,5	26,8	0,50	18/25	124,0	7,3	32,9	0,16	26/47
Oakley ARO3 MIPS	125,7	7,0	30,7	0,16	21/31	107,2	5,1	29,2	0,54	20/29	118,4	6,4	31,1	0,19	23/38
Occano Sport Helmet	133,4	10,2	38,5	0,23	28/54	123,4	7,6	38,0	0,71	28/55	121,4	7,5	39,0	0,26	30/61
Oxford Hurricane F15	141,0	10,4	39,2	0,21	28/54	116,8	8,5	41,1	0,77	33/69	123,8	8,0	35,6	0,22	29/57
POC Omne Air SPIN	145,5	8,4	27,7	0,18	20/28	120,0	7,5	37,7	0,70	29/57	123,9	8,9	34,7	0,18	27/51
Specialized Propero 3 Angi MIPS	128,3	6,3	22,9	0,16	15/18	126,5	4,8	24,0	0,45	18/23	124,8	7,4	31,4	0,15	25/45
Tec Nice	134,7	5,3	22,2	0,21	15/17	151,9	2,6	13,6	0,25	8/8	117,3	4,8	19,8	0,05	17/21
Mean	131,2	7,6	30,0	0,19	21/32	126,8	5,9	31,1	0,58	23/39	124,2	7,4	32,6	0,16	26/47
Min	110,6	3,4	22,2	0,08	11/11	107,2	2,6	13,6	0,25	8/8	106,2	4,8	19,8	0,05	17/21
Max	153,3	10,4	39,2	0,25	28/54	151,9	8,5	41,1	0,77	33/69	146,8	8,9	39,0	0,26	30/61

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