BRA VAL
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2020

Bicycle Helmets 2020
Tested by Folksam

S40456 20-05

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This is why we test bicycle helmets

Every day several cyclists sustain head injuries, which are some of the most serious injuries a cyclist can sustain. Studies from real-life crashes show that bicycle helmets are very effective in reducing serious and fatal 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 serious injuries.

How does a bicycle helmet obtain our "Recommended" label?

Helmets that obtain the best overall results in the bicycle helmet test by Folksam and are given our "Recommended" label. The "Recommended" symbol may only be used for products that have obtained a score at least 15% better than the median value for all tested helmets and the helmet also needs to get a better score than the median for the rotational and translational tests individually.

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Making Roads Safer

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Why is Folksam testing bicycle helmets?
Annually in Sweden over 1000 cyclists have to visit an emergency care centre due to a head injury after a bicycle crash (Stigson 2015). For Great Britain in 2018, the road casualty statistics indicate that 4205 pedal cyclists suffered a serious injury or fatality – more than 11 per day. The hospital data for England Scotland and Wales reveal that 18,546 pedal cyclists were admitted to hospital as the result of a transport-related accident between April 2018 and March 2019. Of these, based on previous matching of hospital and police-reported data, 78 percent are likely to have sustained a head injury (Talbot et al. 2014). Thus, in Great Britain it is likely that 40 cyclists a day are admitted for head injuries. In total 70 percent of the head injuries occur in a single bicycle crash (Stigson 2015). Even though less than a fifth of the head injuries occur when a passenger car was involved, these crashes 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 European market for teenagers and adults. In total, 26 conventional bicycle helmets and one airbag helmet (Hövding 3) were selected from the Swedish and the UK market, Table 1. To ensure that a commonly used representative sample was chosen, the range of helmets available in bicycle/sports shops and in online shops were all considered. Eighteen of the conventional helmets were equipped with technologies aimed to reduce rotational acceleration (15 with MIPS (Multi-directional Impact Protection System), two with SPIN (Shearing Pad INside) and one with WaveCel).

***Table 1**. Included helmets*

Bike helmets	Rotational Technologies	Price (SEK)	Price (GBP)
Abus Hyban 2	–	600	£40
Bell Super Air R MIPS	MIPS	3000	£275
Bell Crest Universal	–	500	£30
Bell Trace MIPS	MIPS	800	£65
Biltema Cykelhjälm MIPS	MIPS	500	–
Biltema Cykelhjälm	–	140	–
Bontrager Solstice MIPS	MIPS	750	£35
Bontrager Specter WaveCel	WaveCel	1700	£130
Closca Design Fuga	–	1100	£100
Giro Caden MIPS	MIPS	1000	£80
Giro Caden	–	650	£60
Giro QUARTER FS MIPS	MIPS	700	£45
Giro Agilis MIPS	MIPS	1000	£90
Halfords Commuter Helmet	–	400	£30
Hövding 3	–	3000	£250
Lazer Blade MIPS	MIPS	1300	£85
OCCANO MIPS HELMET	MIPS	700	–
POC Axion SPIN	SPIN	1600	£125
POC TECTAL SPIN	SPIN	2300	£170
Rockrider MTB ST 500	–	350	£18
Scott Vivo Plus MIPS	MIPS	1600	£85
SMITH Convoy MIPS	MIPS	750	£65
Specialized Ambush ANGI MIPS	MIPS	2200	£130
Specialized S-Works Prevail II ANGI MIPS	MIPS	3200	£170
Sweet Protection Outrider MIPS	MIPS	1500	£140
Tec Quadriga MIPS	MIPS	1600	–
Van Rysel RoadR 900	–	550	£40

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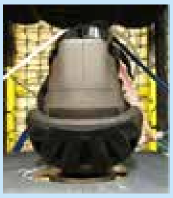
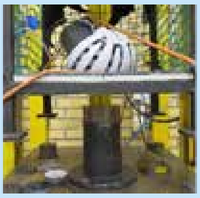
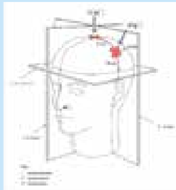
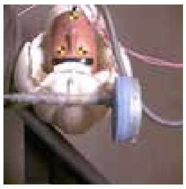
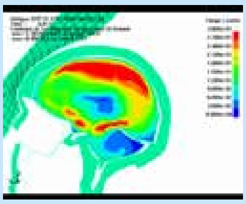
Method
Five physical tests were conducted, two shock absorption tests with straight perpendicular impact and three oblique impact tests (Table 2). The tests were performed by Research Institutes of Sweden (RISE), which is accredited for testing and certification in accordance with the European standard. Computer simulations were subsequently carried out to evaluate the risk for concussion.

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 helmet was impacted at two different locations. One at the top of the head and one at the side of the head, see Table 2.

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).

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.*	

*When testing the Hövding 3, both in the shock absorption tests and in the three oblique tests, an anvil with larger dimensions was used. The reason was that if Hövding 3 had been tested against the anvil used for a conventional helmet, there was a risk it could get in contact with the sharp edges of the anvil. The Hövding 3 was pre-inflated and had a pressure of 0.56 bar.

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Rating of Helmets
The safety level of a helmet was rated relative to the average test result for all helmets tested (by comparing with the median value). Since the most common brain injuries often occur in oblique impacts the three oblique tests influenced the rating to a greater extent. The overall result was calculated according to the equation below, where T1 and T2 are the relative results in shock absorption and T3-5 are the relative results in the oblique impact tests. To obtain the best overall result and thereby be awarded our "Recommended" label, the helmet needs to perform better than the median in both the shock absorption test and the oblique impact test.

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

Results
In total eight helmets obtained the Folksam "Recommended" label: Hövding 3, Biltema Cykelhjälm MIPS, Tec Quadriga MIPS, Scott Vivo Plus MIPS, Bell Super Air R MIPS, Bontrager Specter WaveCel, OCCANO MIPS HELMET and Specialized S-Works Prevail II/ ANGI MIPS, Table 3. These helmets performed 18-76% better than the average helmet. The Hövding 3 head protector, which protects the head with an airbag in the event of an accident, obtained the overall best result. All seven conventional bicycle helmets are fitted with systems (Multi-directional Impact Protection System, MIPS or WaveCel) aimed at reducing rotational energy.

***Table 3**. Overall results*

Helmets 2020	Overall result	Folksam Recommended
Abus Hyban 2	-13%	
Bell Crest Universal	-36%	
Bell Super Air R MIPS	19%	Recommended
Bell Trace MIPS	20%*	
Biltema Cykelhjälm	-10%	
Biltema Cykelhjälm MIPS	37%	Recommended
Bontrager Solstice MIPS	15%*	
Bontrager Specter WaveCel	18%	Recommended
Closca Design Fuga	-6%	
Giro Agilis MIPS	-8%	
Giro Caden	-37%	
Giro Caden MIPS	-13%	
Giro QUARTER FS MIPS	-1%	
Halfords Commuter Helmet	-33%	
Hövding 3	76%	Recommended
Lazer Blade MIPS	15%*	
OCCANO MIPS HELMET	18%	Recommended
POC Axion SPIN	3%	
POC TECTAL SPIN	-13%	
Rockrider MTB ST 500	-12%	
Scott Vivo Plus MIPS	22%	Recommended
SMITH Convoy MIPS	-17%	
Specialized Ambush ANGI MIPS	-4%	
Specialized S-Works Prevail II ANGI MIPS	18%	Recommended
Sweet Protection Outrider MIPS	3%	
Tec Quadriga MIPS	23%	Recommended
Van Rysel RoadR 900	-14%	

* The helmet performed higher than the median in the shock absorption test.

All helmets scored lower than 250 g in resultant acceleration in the shock absorption test (Figure 1). The lowest values were measured for Hövding 3 (40 g) and Specialized S-Works Prevail II ANGI MIPS (126 g). The Hövding 3 performed at least three times better than all the other conventional helmets (40 g vs. other helmets that were around 171 g).

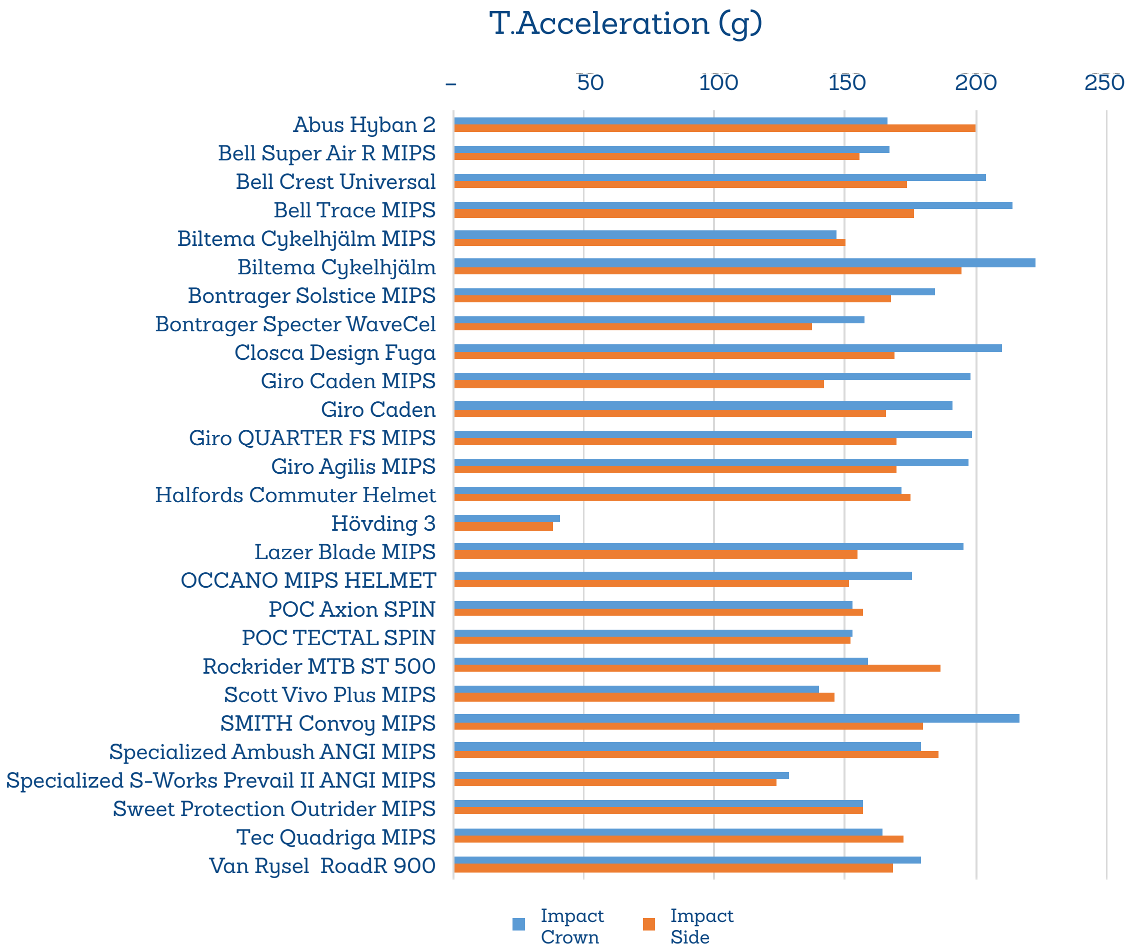

***Figure 1**. Shock Absorption measuring linear acceleration*

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 12% to 32%. In total four 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 systems aiming to reduce energy performed better than the others.

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)					
Bicycle Helmet	T. ACC. [g]	R. ACC. [rad /s^2]	R. V [rad/s]	BrIC	Strain [%]	Risk of Concussion [%]	T. ACC. [g]	R. ACC. [rad /s^2]	R. V [rad/s]	BrIC	Strain [%]	Risk of Concussion [%]	T. ACC. [g]	R. ACC. [rad /s^2]	R. V [rad/s]	BrIC	Strain [%]	Risk of Concussion [%]
Abus Hyban 2	138,3	5754	27,0	0,46	22	34	127,3	6883	32,1	0,60	33	69	122,3	5828	29,4	0,66	36	78
Bell Crest Universal	137,1	8343	33,1	0,55	30	59	126,5	8548	35,8	0,66	38	82	120,0	6330	30,5	0,67	35	75
Bell Super Air R MIPS	105,0	4108	24,3	0,42	17	22	120,9	4632	25,2	0,48	22	36	113,8	4565	23,9	0,56	30	61
Bell Trace MIPS	126,7	4448	17,1	0,28	13	14	127,2	4730	22,3	0,41	20	29	107,9	4768	22,3	0,48	31	63
Biltema Cykelhjälm	125,3	7163	25,2	0,44	22	33	113,3	6026	28,2	0,52	28	53	108,7	6013	31,8	0,70	35	75
Biltema Cykelhjälm MIPS	132,1	5081	18,3	0,33	15	17	117,7	3641	17,5	0,33	15	16	133,3	4814	18,8	0,38	26	48
Bontrager Solstice MIPS	124,2	4707	19,6	0,33	15	18	112,8	5620	28,2	0,52	27	50	114,3	5268	22,5	0,50	29	56
Bontrager Specter WaveCel	111,3	4810	19,5	0,35	16	18	91,7	4117	26,5	0,50	23	37	105,5	6027	29,3	0,68	36	78
Closca Design Fuga	139,6	6223	26,5	0,43	21	33	138,8	7236	31,8	0,60	31	65	114,8	5345	26,7	0,58	30	62
Giro Caden MIPS	112,0	6277	28,1	0,45	25	44	123,9	6418	28,8	0,54	27	52	107,9	5804	26,3	0,57	35	76
Giro Caden	131,2	9526	32,9	0,52	30	60	121,1	7889	37,8	0,70	37	79	111,4	7473	32,5	0,73	40	86
Giro QUARTER FS MIPS	125,5	6075	23,1	0,39	19	26	121,3	7135	29,4	0,55	29	57	106,1	5626	29,4	0,65	37	81
Giro Agilis MIPS	132,3	6101	23,8	0,38	19	27	113,2	6479	31,8	0,59	31	63	107,7	6260	32,5	0,70	40	85
Halfords Commuter Helmet	126,2	9430	37,6	0,60	35	75	109,6	6077	30,9	0,57	30	61	112,1	5917	28,9	0,65	32	67
Hövding 3	33,1	1456	21,3	0,38	12	12	29,5	1708	15,9	0,28	11	12	27,0	2703	16,5	0,31	11	11
Lazer Blade MIPS	120,3	5408	24,1	0,41	19	27	129,8	6274	25,9	0,48	24	42	116,1	4171	20,4	0,47	26	47
OCCANO MIPS HELMET	129,6	4367	14,4	0,27	12	12	101,1	5019	26,3	0,50	25	43	109,6	5981	28,7	0,66	36	77
POC Axion SPIN	118,7	6514	30,0	0,53	24	40	122,4	5953	28,8	0,53	28	53	99,6	4760	23,1	0,52	28	54
POC Tectal SPIN	122,2	6737	30,9	0,55	26	46	105,6	5953	34,4	0,63	32	67	104,0	5727	27,7	0,63	34	72
Rockrider MTB ST 500	133,6	8703	25,5	0,44	23	37	136,2	8010	33,8	0,62	34	73	111,8	5761	25,3	0,60	33	70
Scott Vivo Plus MIPS	116,3	4862	18,7	0,33	16	18	106,4	5014	24,6	0,46	23	38	108,7	5162	25,6	0,59	33	70
SMITH Convoy MIPS	148,6	7084	26,8	0,48	24	42	117,9	6874	32,4	0,60	32	66	106,5	5738	26,1	0,61	33	69
Specialized Ambush ANGI MIPS	119,1	5755	25,9	0,43	21	32	114,0	5999	29,5	0,55	29	56	105,7	5360	26,1	0,57	34	71
Specialized S-Works Prevail II ANGI MIPS	105,3	4679	21,4	0,36	18	24	80,3	3465	26,5	0,49	23	38	81,2	6033	30,4	0,66	37	80
Sweet Protection Outrider MIPS	103,5	7275	29,2	0,48	25	44	97,5	4527	24,4	0,45	23	38	93,3	4982	24,4	0,55	30	62
Tec Quadriga MIPS	105,9	4714	16,7	0,32	13	14	100,2	5207	27,9	0,52	25	45	120,5	4523	18,9	0,39	26	49
Van Rysel RoadR 900	128,7	5931	27,4	0,47	23	36	127,4	7720	34,9	0,65	34	74	106,2	6238	27,6	0,59	36	77
Mean	120,4	5983	24,8	0,42	21	32	112,4	5821	28,6	0,53	27	52	106,5	5451	26,1	0,58	32	67
Median	125,3	5931	25,2	0,43	21	32	117,7	5999	28,8	0,5	30	53	108,7	5727	26,3	0,6	30	70
Min	33,1	1456	14,4	0,27	12	12	29,5	1708	15,9	0,28	12	12	27,0	2703	16,5	0,31	12	11
Max	148,6	9526	37,6	0,60	35	75	138,8	8548	37,8	0,70	35	82	133,3	7473	32,5	0,73	35	86

Discussion

With the aim to guide consumers to buy the safest bicycle helmets and to influence helmet design and the safety standard of helmets, this test series was conducted by Folksam Insurance Group in Sweden with funding support from the Road Safety Trust in the UK. Our hope is that more organisations will be able to join future test series. A large international consumer test consortium has the potential to effectively raise the safety standard of helmets. Folksam initiated consumer tests of bicycle helmets in 2012 because the certification test standards of helmets are not sufficient, as it does not cover the helmets' capacity to reduce rotational acceleration, i.e., when the head is exposed to rotation due to the impact. In the current European certification tests, however, only the energy absorption in a perpendicular impact is evaluated, with the helmet being dropped straight onto a flat anvil and onto a kerbstone anvil. The pass-fail criteria used in the test standard is relatively high (250 g), mainly with a focus on avoiding skull fractures. However, concussion occurs in many bicycle accidents, often as a result of the brain being subjected/exposed to rotational forces in the event of either direct or indirect forces towards the head. In general, 8% of concussions result in long-term or permanent symptoms, such as memory disorders, headaches and other neurological symptoms. This clearly shows the importance of preventing these injuries. Therefore, an improved test method, including oblique impacts, was used to also mirror a common bicycle accident where the cyclist falls to the ground, striking the head at an angle creating a rotation of the head, with concussion as a common injury outcome.

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 European market. They also indicate that there is a link between rotational energy and strain in the grey matter of the brain. In the future, certification helmet requirements should therefore ensure a good performance for rotational loading as well as direct loading. Before this happens, consumer tests can play an important role in informing and guiding consumers in their choice of helmets. Since 2012 Folksam have conducted twelve consumer helmet tests (eight 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 at reducing rotational acceleration has increased even though this was not required to pass the certification test. In the present test 18 out of 29 had some of these technologies. In general, helmets equipped with technologies aimed to reduce rotational acceleration 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. In addition to an improved performance regarding protection of rotational loading, helmets also need to absorb energy more effectively.

Note

This report was part funded by the Road Safety Trust, an independent grant-giving trust working hard to reduce the numbers of people killed or injured on UK roads through providing independent funding for vital research and practical interventions into new approaches to road safety. Folksam, Road Safety Trust or any of the researchers have no interest in any of the companies/products tested.

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