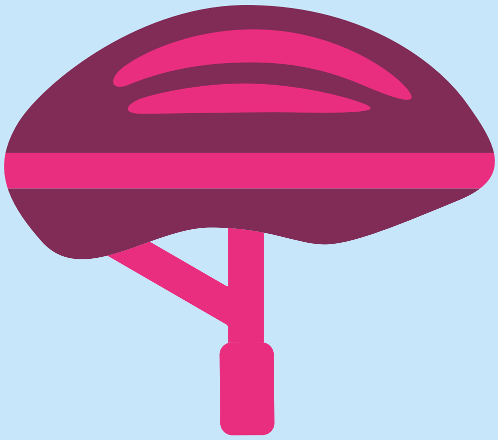


Bicycle Helmets 2023
Tested by Folksam

S41102 23-05

Folksam

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 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.

Helena Stigson

Helena Stigson, PhD
Associate Professor
Traffic Safety Research

Folksam

Why does Folksam test adult 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). 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 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 collision, impact to the head will be oblique (Willinger, Deck et al. 2014, Fahlstedt 2015, Bland, McNally 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, 16 conventional bicycle helmets were selected from the Swedish 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. All but two of the helmets were equipped with technologies aimed at reducing rotational acceleration (13 with MIPS (Multi-directional Impact Protection System), and one with Lacer KinetiCore.

Table 1. Included helmets

Bike helmets	Rotational Technologies	Price (SEK)
Abus Macator MIPS	MIPS	900
Abus Modrop Mips	MIPS	1 300
Bell Tracker	-	400
Bell XR Spherical	MIPS	2 100
Everest U Trail Nfc	MIPS	1 200
Giro Fixture MIPS II	MIPS	800
Lazer One	MIPS	800
Lazer Tonic Kineticore	Kineticore	800
Livall C20	-	700
Occano U COMMUTE MIPS HLM	MIPS	900
POC Pocito Crane MIPS	MIPS	1 000
POC Ventral Air Mips	MIPS	2 500
Scott Supra Plus	MIPS	800
Scott Tago Plus	MIPS	1 700
Specialized Mode	MIPS	1 100
Specialized S-Works Prevail 3	MIPS	3 700

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 of concussion.

Shock Absorption Test

The helmet was dropped from a height of 1.5m onto a horizontal surface according to the European standard (EN1078 2012), which sets a maximum acceleration of 250g. 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.

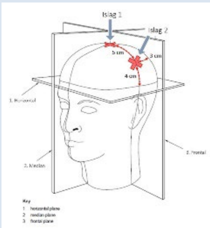
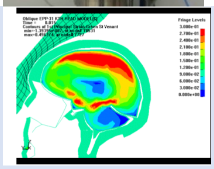
Oblique Tests

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 an additional test under consideration within the CEN Working Group's 11 "Rotational test methods" (Willinger, Deck 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, McIntosh et al. 2013, Fahlstedt, Meng et al. 2022). 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). The risk curve presented by Fahlstedt et al (2022) was used to estimate the risk for concussion.

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 30% corresponds to a 50% risk for concussion.			

Rating of Helmets

The safety level of a helmet was rated relative to the median value for the test results of all the helmets included in test runs conducted in 2020, 2021 and 2023. In previous tests, the safety assessment has only been made by relating the helmets' measured values to the median value from that test series. This year, however, the median calculation has been made by using measurement data from three latest test runs to provide a more stable calculation basis and to reduce the influence of an individual helmet on the median calculation. 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, three helmets obtained the Folksam “Recommended” label: l: Bell XR Spherical, Scott Tago Plus och Specialized S-Works Prevail 3, Table 3. These helmets performed 21-25% better than the average helmet. All these three helmets are fitted with are fitted with systems (Multi-directional Impact Protection System, MIPS) designed to reduce rotational energy.

Table 3. Overall results

Helmets 2023	Overall result	Folksam Recommended
Abus Macator MIPS	21%*	
Abus Modrop Mips	-15%	
Bell Tracker	-86%	
Bell XR Spherical	36%	Recommended
Everest U Trail Nfc	3%	
Giro Fixture MIPS II	-38%	
Lazer One	21%*	
Lazer Tonic Kineticore	-73%	
Livall C20	-49%	
Occano U COMMUTE MIPS HLM	9%	
POC Pocito Crane MIPS	-11%	
POC Ventral Air Mips	-12%	
Scott Supra Plus	-38%	
Scott Tago Plus	15%	Recommended
Specialized Mode	16%*	
Specialized S-Works Prevail 3	16%	Recommended

* The helmet’s results were worse than the median in at least one of the tests.

All helmets scored lower than 250g in resultant acceleration in the shock absorption test (Figure 1). The lowest values were measured for Poc Ventral Air Mips (118g impact to the crown and 129g impact to the side of the helmet).

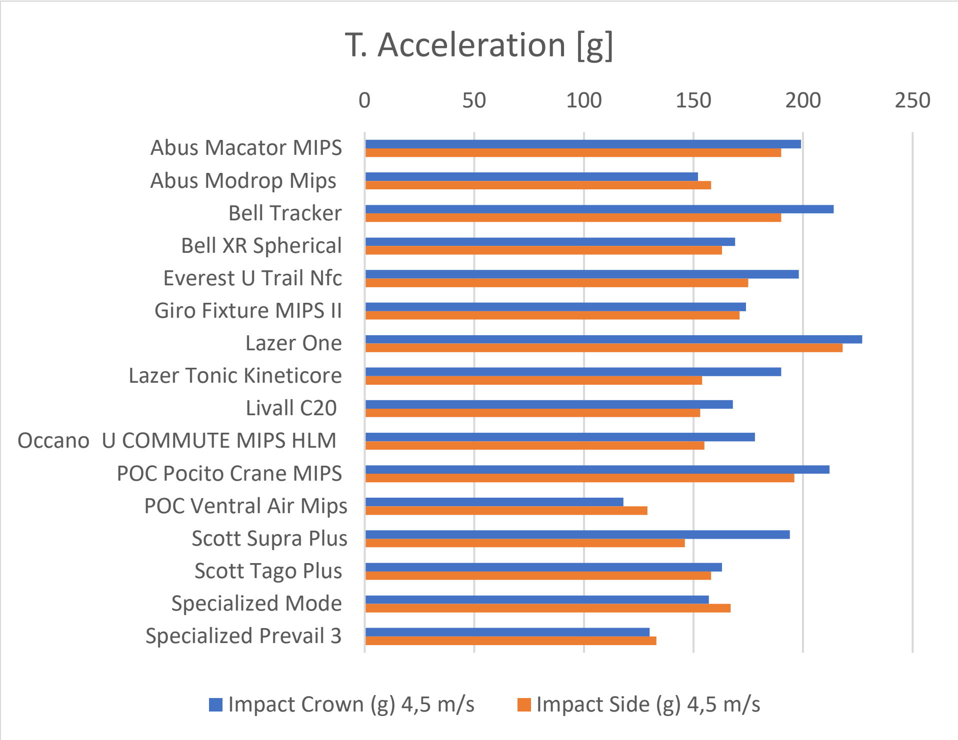


Figure 1. Shock absorption measuring linear acceleration

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 whole brain during oblique impacts could vary between helmets, from 15% to 41%. Six helmets got a result that was below the threshold for a 50% risk of concussion in all the tests.

Discussion

With the aim of guiding consumers in the purchase of the safest bicycle helmets and influencing helmet design and the safety standard, this test series was conducted by Folksam Insurance Group in Sweden. Folksam was the first organisation around the world to initiate the consumer testing of bicycle helmets aimed at examining helmet performance in both direct and oblique impact. Today, several new test protocols exist. From a consumer perspective there are both pros and cons with harmonising test protocols and ratings. However, 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 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 (250g), 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 brain. In 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 sixteen consumer helmet tests (eleven bicycle helmet tests, three 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 2023 test round, all but two helmet had some of these technologies. Previous tests have shown that helmets equipped with technologies aimed at reducing rotational acceleration performed in general better than the others. However, all helmets need to reduce rotational acceleration more effectively. The initial objective of the helmet standard EN 1078 was to prevent life threatening injuries, but with the knowledge we have today, helmets should preferably also prevent brain injuries that have long-term consequences. Therefore, helmets should be designed to reduce translational acceleration as well as rotational acceleration. A conventional helmet that meets current EN 1078 standard does not prevent a cyclist from sustaining a concussion in the event of a head impact. In addition to an improved performance regarding protection of rotational loading, helmets also need to absorb energy more effectively. The safety standard EN 1078 that needs to be met for any bicycle helmet sold in the EU to obtain the CE mark should be seen as a minimum requirement. The potential outcome is that bicycle helmets meeting the EN 1078 standard requirements may not sufficiently protect in real-life collisions or falls.

Table 3. 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. [rad /s²]	R. V [rad/s]	BrIC	Strain	Risk of Concussion [%]	T. ACC. [g]	R. ACC. [rad/s²]	R. V [rad/s]	BrIC	Strain	Risk of Concussion [%]	T. ACC. [g]	R. ACC. [rad/s²]	R. V [rad/s]	BrIC	Strain	Risk of Concussion [%]
ABUS MACATOR MIPS	156.8	5170.6	13.9	0.23	20%	17%	154.9	5648.9	20.0	0.36	23%	26%	123.6	5258.9	14.6	0.32	19%	15%
ABUS MODROP MIPS	113.7	5485.1	23.6	0.38	22%	24%	113.5	6229.2	31.3	0.55	33%	63%	112.7	5637.8	24.3	0.56	32%	58%
BELL TRACKER	179.2	9768.4	30.1	0.49	33%	63%	145.9	9856.9	34.6	0.62	39%	82%	132.4	9159.0	28.1	0.62	36%	72%
BELL XR SPHERICAL	99.1	5728.6	18.6	0.33	16%	9%	110.0	3404.5	20.3	0.36	19%	16%	108.3	6772.0	21.2	0.43	25%	32%
EVEREST U TRAIL NFC	144.0	6798.4	18.7	0.31	18%	13%	140.1	5866.6	27.7	0.49	29%	48%	145.5	8746.5	22.1	0.50	30%	51%
GIRO FIXTURE MIPS II	122.8	8657.1	26.5	0.43	27%	41%	127.6	7412.9	32.4	0.58	36%	72%	109.4	5623.3	22.0	0.50	28%	45%
LAZER ONE	151.7	4883.7	15.6	0.27	16%	10%	149.1	4121.0	20.8	0.38	20%	20%	125.4	6727.4	22.3	0.55	25%	35%
LAZER TONIC KINETICORE	151.7	11093.9	34.4	0.55	31%	56%	135.8	9131.2	36.8	0.65	41%	85%	139.3	7908.0	29.3	0.68	35%	71%
LIVALL C20	119.6	9120.4	31.5	0.52	26%	36%	126.1	9657.4	34.7	0.62	39%	80%	120.3	9573.4	33.2	0.75	40%	85%
OCCANO U COMMUTE MIPS HLM	128.0	5154.6	17.5	0.30	18%	14%	127.2	5923.6	29.0	0.52	31%	56%	103.1	3914.2	19.2	0.44	25%	35%
POC POCITO CRANE MIPS	135.0	6906.3	20.5	0.35	20%	18%	133.9	8407.1	28.4	0.51	28%	43%	95.1	7239.3	33.3	0.75	35%	69%
POC VENTRAL AIR MIPS	95.1	4873.4	27.3	0.45	22%	26%	95.2	4752.0	29.3	0.52	28%	45%	92.0	5917.7	26.8	0.59	41%	87%
SCOTT SUPRA PLUS	137.2	7858.1	13.4	0.25	26%	36%	114.8	5753.6	27.0	0.48	37%	75%	99.5	5432.6	16.6	0.35	32%	59%
SCOTT TAGO PLUS	124.7	6958.4	29.3	0.47	20%	19%	103.7	6052.9	33.4	0.59	27%	40%	111.1	8775.5	27.2	0.63	22%	24%
SPECIALIZED MODE	96.5	6421.1	28.1	0.47	22%	25%	104.9	3083.5	20.6	0.37	17%	11%	107.0	5950.7	23.3	0.56	27%	42%
SPECIALIZED S-WORKS PREVAIL 3	107.1	5865.8	23.2	0.39	19%	16%	85.2	4592.5	29.2	0.52	28%	44%	118.3	5719.5	21.2	0.48	28%	43%

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