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Saving More Lives

Cyclist Head Injuries: A Persistent Challenge

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Introduction

Many governments around the world promote more cycling as an active mode of travel due to its health and environmental benefits. However, cyclist crashes are common and health consequences can be substantial. In Sweden, more than half of all seriously injured road users are cyclists [1]. Most cyclists get injured in single-vehicle collisions, that is with no other vehicle involved. However, when another vehicle is involved, the consequences are often more severe [2] – in about one third of fatal bicycle crashes another vehicle was involved*. Importantly, the numbers are on the rise. In the EU, cyclists are the only mode of transport that has shown no decline in fatalities over the past decade. Furthermore, serious injuries in crashes involving a cyclist showed the greatest increase in serious injuries for any transport mode (+24%), from 2010 to 2019**.

For an injured bicyclist, head injuries are very common. A recent study [3] ranked the head as the body region most frequently injured with at least serious severity.

Autoliv research has identified common head injuries as including the brain injuries ‘cerebral concussion’ and other serious injuries to the cerebrum, as well as facial bone (maxilla) fractures and fractures to the base of the skull. These head injuries can lead to grave consequences [4]. Approximately half of the fatal injuries for cyclists were to the head, which is a higher percentage than for any other mode of travel.

When the head hits an object at speed and makes direct contact, the skull will deform, which can result in fractures of the skull and facial bones. Additionally, when the head goes through sudden movements it experiences translational or rotational accelerations. These accelerations can cause brain injury even without a fracture of the skull, for example concussion or more serious brain or blood vessel injuries [5].

But There Is Something We Can Do About It

The situation is not as bleak as it might seem. There are things that can be done to reduce the number of injured and killed bicyclists. A wide range of countermeasures exist, but are not yet fully implemented, which could reduce injuries from crashes by as much as 56% [6]. These countermeasures include improved maintenance, de-icing and removal of snow from bicycle and non-bicycle infrastructure, improved vehicle crashworthiness and Advanced Emergency Braking with cyclist detection for passenger cars, a vehicle mounted bicyclist protection airbag and increased helmet use.

Autoliv’s research confirms the potential head injury reducing benefits of a helmet and bicyclist protection airbag using advanced computer simulations of car-to-bicycle crashes with a virtual Human Body Model. In this work it was found that a bicycle helmet significantly reduced head injury risk and a vehicle mounted bicyclist protection airbag reduced the injury risk even further [7].

Bicycle helmet use reduces the risk for ‘head injury’, ‘serious head injury’, ‘facial injury’ and ‘fatal head injury’ [8]. Bicycle helmet use is not associated with engaging in risky behaviour [9] and infrastructure and safety concerns are more often cited as barriers to cycling than helmet wearing [10].

Using a helmet is a good thing, but how do we know how good a given helmet is?

How Good Is a Helmet Really?

Helmets approved according to the CE standard are guaranteed to give some energy absorption in perpendicular impacts (EN1078: 2012; at 5.42 m/s on a flat anvil and 4.57 m/s on a kerbstone – equivalent to drop heights of about 1.5 m and 1.1 m respectively). This ensures a minimum requirement for the level of shock absorbing capacity for the crown, and the parts of the forehead, rear, sides and temples of the head covered by the defined testing area.

If all helmets are good, which one should I buy? To answer this question, there are ratings to assess the protection performance of helmets and guide consumers towards differences from one helmet to another. The consumer information assessments go beyond the tests in the standard requirements adding other conditions, reinforcing the relationship to real world impact conditions. Examples are the Virginia Tech Helmet Ratings*** and the Folksam Bicycle Helmet Testing****.

The Folksam helmet rating includes linear Shock Absorption Tests and Oblique Tests in which a head form with a helmet is dropped from heights of 1.1 m and 2.0 m respectively. The oblique impact tests are complemented with a finite element model of the brain to compute concussion risk. Thereby, the tests assess the risk of both skull fractures from direct loading, as well as the risk for brain injuries from translational and rotational loading. Test heights (speeds) are intentionally different from those in the standards to complement the minimum requirements with additional insights into helmet performance.

However, test scenarios in a laboratory setting will never completely address the diversity of bicycle crashes in the real world, and all the potential different head impact conditions that can and do occur. As a simple but important example, crashes can occur at higher speeds than the drop tests potentially exceeding protection levels offered by helmets. Therefore, despite using helmets, head injuries still occur in bicyclist impacts.

We started a development journey here, asking ourselves, what could be done to excel in current test scenarios and push the envelope towards even more shock absorbing capacity?

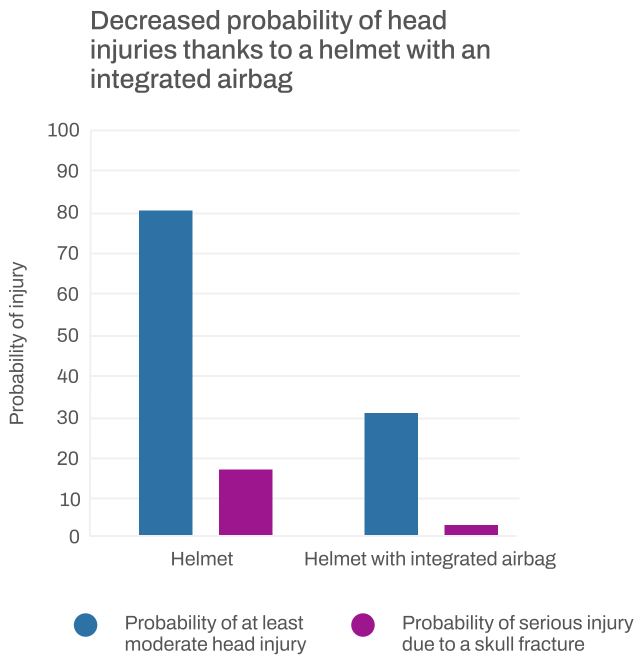
What Did We Do?

In a common prestudy Autoliv and POC aimed to bring together core competencies in order to explore the potential improved injury reducing benefits of integrating an airbag in a helmet. The goal was a bicycle helmet with low mass and attractive design that, when needed, can expand and provide the bicyclist with protection far beyond current state-of-the art bicycle helmets. A development boundary being that in situations when the airbag is not deployed the helmet should still meet all the usual safety requirements and provide the bicyclist with levels of protection expected from a conventional helmet.

The helmet with integrated airbag was developed by combining advanced mathematical modelling with mechanical testing in a series of design and evaluation loops. The helmet with the integrated airbag was positioned on a crash test dummy head. The helmeted head was then dropped onto either flat or angled surfaces to mimic a head impact with the ground from a bicyclist fall. The drop height was either 1.5 or 1.8 m in these prestudy tests. Different airbag designs, pressures and integration methods were evaluated first in simulation and thereafter the most promising concept was evaluated by means of mechanical tests with prototype airbags (refer to drop test picture).

The prestudy included exploration of a specification for a suitable system, Electronic Control Unit (ECU), to trigger the airbag. For future training of the triggering decision, some event data was collected from cyclists, including artificial recreation of fall and near fall conditions.

The drop Test. The height was either 1.5 or 1.8 m in these prestudy tests.



What Did We Get?

The resulting concept was an airbag consisting of three fabric channels hidden in the helmet during normal use. In a crash the channels were expanded covering the sides and top of the head and pressurised to approximately 60 kPa. When deployed the airbag acts as the initial energy absorber while the underlying helmet may still contribute in the usual way. The combination of both absorbing technologies enables a reduction of the head acceleration and significantly reduced head injury risk in impact tests (refer to chart). Targets such as having a low mass, good coverage, and not being visible during normal use were fulfilled with this airbag design.

Where Do We Go From Here?

We are confident that our solution can provide additional safety for helmet wearers and so we will continue our journey in a second phase. A focus now is on optimising the airbag coverage area in order to offer the greatest injury prevention potential whilst reflecting common head or helmet contact locations and design constraints. The targets are coming from parallel studies of real-life accident video material (POC) and data queries from in-depth road-traffic collision data (Autoliv). The intention being to set the design direction through a balanced analysis of contact frequency and severity of outcome across different head regions.

These studies may help in determining a range of observable real-life impact velocities, which would support the derivation of more challenging test conditions and hence evaluation of the helmet with an integrated airbag in other realistic scenarios. For instance, it could mean a drop test with an impact speed above that of today's standard and ratings tests. This second phase will also include further evaluation of the airbag technology's potential to provide safety with respect to angled loading and rotational injury mechanisms.

Autoliv x POC

How about other vulnerable road users?

As urban mobility is being reshaped, with the emergence of e-bike commuting, we believe it is necessary to continue exploring enhanced safety for vulnerable road users. Here we have focussed on a solution that protects against head injury for bicyclists, but the understanding of these priority injuries and potential countermeasures is not only applicable for the safety of bicycle and e-bike riders. Many aspects transfer across transport modes are also relevant for the safety of those who ride mopeds, motorcycles and other micro-mobility.

What should we expect to see next?

Improved bicyclist head protection must be maintained on the agenda. Therefore, Autoliv will collaborate on related projects and continue to publish insights into the injury problem description. Watch out for conference presentations and journal articles on cyclist head injuries.

This countermeasure – a helmet with an integrated airbag – was so far proven to reduce head injury risk substantially in impact tests. The successful outcome of the pre-study will now lead to further testing and refinement with the objective of developing the concept further and potentially bringing a product to the market.

Reference

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