This symposium is supported by COST Action TU1101: Towards safer bicycling through optimization of bicycle helmets and usage

Symposium

Kinesiology for the Future:

Bicycle Traffic Safety and Helmets

9th of May 2012, Koper, Slovenia

Book of abstracts

Bogerd CP, Bogerd N, Dodič Fikfak M, Otte D, Walker I & Pišot R

Organizers:

UNIVERZA NA PRIMORSKEM
UNIVERSITÀ DEL LITORALE

INSTITUTE FOR KINESIOLOGY RESEARCH

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Book of abstracts of the symposium

Kinesiology for the Future:

Bicycle Traffic Safety and Helmets

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Preface

We cordially welcome you to our symposium «Kinesiology for the Future: Bicycle Traffic Safety and Helmets». This symposium targets to give an overview of the state-of-the-art of relevant aspects of bicycle traffic safety and helmets. The symposium aims at establishing active communication among scientists, university students, end-users organizations, legislators, manufacturers, and other stakeholders.

We are very grateful to our sponsors who financially enabled this symposium, but also to the Institute of Kinesiology Research of the University of Primorska who supported the organizers to invest time in this symposium.

Let this symposium inspire and motivate you in your work towards the common goal of increasing safety of bicyclists in traffic.

Dr. Cornelis P (Niels) Bogerd

Chair of the scientific committee of the present symposium

Presentation of the organizing institutions

The main organizing institutions of this symposium are the Institute of Kinesiology Research (UP IKARUS) and the Faculty of Ergonomics and Kinesiology (UP FENIKS). UP IKARUS focusses mainly on research and is part of the Science and Research Centre, whereas UP FENIKS focusses mainly on education. Both are part of the University of Primorska (UP) based in Koper, Slovenia. Below you find an overview of what we stand for. We believe that the present symposium stimulates traffic safety for bicyclist, allowing society to fully benefit from the positive effects of bicycling, e.g., reduced traffic congestion, reduced air and noise pollution, and increase health benefits.

Mission

We aim to contribute to the quality of life of individuals and the society by educating, creating, developing, and transferring quality knowledge in all integrative areas of ergonomics and kinesiology.

Vision

We encourage quality, creativity, and cooperation on an (inter)national level. It integrates the aspects of ergonomics and kinesiology in the society, thereby contributing to its welfare.

Education

Central to our education are: responsibility, team work, expertise in ergonomics and kinesiology, critical and constructive thinking. The study program is student centered and is based on the latest empirical research. We follow contemporary European guidelines in the field of the quality of work with regards to lecturers and other co-workers.

Science

Central to our scientific studies is improving quality of the life of individuals and the society. Relevant problems are being addressed through research in the field of fundamental and applied science, focusing on resolving relevant research problems.

Transfer of knowledge

We focus on transferring scientific knowledge of solutions for relevant problems. We establish cooperation with knowledge facilitators and encourage mutual impact on the transfer of competences among students, teachers, and researchers.

Prof. Dr. Rado Pišot

Head of the Institute of Kinesiology Research

Interim dean of the Faculty of Ergonomics and Kinesiology

Presentation of the co-organizing institution

The Clinical Institute of Occupational, Traffic and Sports Medicine (CIOTSM) acts as the co-organizing institution of the present symposium. This institution is part of the University Medical Centre Ljubljana (UMCL). The UMCL is a public institution, whose main functions are the provision of secondary and tertiary healthcare, education, and research.

With its divisions, institutes, departments, and other organizational units, the UMCL provides hospital and specialist outpatient care for the Ljubljana health region as well as other regions if they lack adequate healthcare at the regional level, and tertiary healthcare.

Tertiary healthcare entails care for the balanced development of specialized healthcare in Slovenia, introduction of new healthcare methods, conveying new knowledge and skills to other health institutions, providing the most demanding health services, and taking health measures necessary for performing educational activities.

Educational activity provided by the UMCL includes the following:

- Performing educational activities for the needs of medical faculties, university colleges of healthcare, faculties of pharmacy, and other schools at the secondary, undergraduate, and graduate levels;
- Offering graduate courses for medical and allied professionals, and others;
- Improving the professional, teaching, and research skills of its employees.

Research at the UMCL includes:

- Conducting research as part of the health protection plan and the national research program;
- Conducting research for clients in Slovenia and abroad;
- Training research assistants;
- Organizing research and professional conferences.

The Clinical Institute of Occupational, Traffic, and Sports Medicine (CIOTSM) is an independent unit within the UMC. Its 26 staff members primarily seek to improve employee, drivers and athletes health. Work of CIOTSM is mostly prevention at the secondary and tertiary level in the field of employee, drivers and athletes. It directs its efforts into constant development of employee and drivers health doctrines and workplace health promotion, in concordance with modern European guidelines, as well as for practical changes benefiting employee health. It strives to increase the humanization of work and traffic and to realize the imperative on adapting workplaces to employees. Its projects and programs include various target groups from the very start. It maintains various methods of communications with companies, trade unions, human resource managers, management and mass media.

Dr. Metoda Dodič Fikfak

Head of the Clinical Institute of Occupational, Traffic and Sports Medicine

Presentation of COST Action TU1101

COST Action TU1101 supports the present symposium. This Action is titled «Towards safer bicycling through optimization of bicycle helmets and usage» and is motivated as follows: Cycling is an excellent sustainable alternative to driving for many journeys. However, cyclists have fewer safety options than car-users, with a helmet being the main safety device that is available. Nonetheless, there are strong indications that increasing bicycle helmet usage for cyclists through legislation causes confounding factors which might cancel out the positive effect of helmets on head and brain injury. Furthermore, current helmet design is suboptimal. Since several fields are important to bicycle helmet optimization, a combined effort involving all of these is necessary so that a given parameter is not optimized at the cost of another. This multidisciplinary approach respects the complex nature of the issue, is unique in Europe, and will provide more complete information to legislators, manufacturers, end-users, and scientists, ultimately leading to increased safety for cyclists.

The main objectives of this Action is to increase scientific knowledge concerning bicycle helmets regarding traffic safety and to disseminate this knowledge to stakeholders, including cyclists, legislators, manufacturers, and the scientific community. An additional aim is to stimulate international collaboration within the domain of this Action.

Currently, more than 40 experts representing over 15 countries take part in this Action, and we continue accepting members which contribute to reaching the Action’s objectives. The Action started in October 2011 and will finish in October 2015.

Working groups

WG1 In-depth accident observations and injury statistics

WG2 Traffic psychology

WG3 Impact engineering

WG4 Ergonomics of thermal aspects

Website

www.cost.esf.org/domains_actions/tud/Actions/TU1101

Presentation of COST

COST Action TU1101 is funded by COST. COST – the acronym for European COoperation in the field of Scientific and Technical Research – is the oldest and widest European intergovernmental network for cooperation in research. Established by the Ministerial Conference in November 1971, COST is presently used by the scientific communities of 35 European countries to cooperate in common research projects supported by national funds.

The funds provided by COST - less than 1% of the total value of the projects - support the COST cooperation networks (COST Actions) through which, with EUR 30 million per year, more than 30.000 European scientists are involved in research having a total value which exceeds EUR 2 billion per year. This is the financial worth of the European added value which COST achieves.

A “bottom up approach” (the initiative of launching a COST Action comes from the European scientists themselves), “à la carte participation” (only countries interested in the Action participate), “equality of access” (participation is open also to the scientific communities of countries not belonging to the European Union) and “flexible structure” (easy implementation and light management of the research initiatives) are the main characteristics of COST.

As precursor of advanced multidisciplinary research COST has a very important role for the realisation of the European Research Area (ERA) anticipating and complementing the activities of the Framework Programmes, constituting a “bridge” towards the scientific communities of emerging countries, increasing the mobility of researchers across Europe and fostering the establishment of “Networks of Excellence” in many key scientific domains such as: Biomedicine and Molecular Biosciences; Food and Agriculture; Forests, their Products and Services; Materials, Physical and Nanosciences; Chemistry and Molecular Sciences and Technologies; Earth System Science and Environmental Management; Information and Communication Technologies; Transport and Urban Development; Individuals, Societies, Cultures and Health. It covers basic and more applied research and also addresses issues of pre-normative nature or of societal importance.

Website: www.cost.eu

Program

Registration		**8:30**
1. Opening ceremony		**9:00**
Mr. Tomaž Gantar (minister of health) Prof. Dr. D. Marušič (rector) Prof. Dr. D. Darovec (director) Prof. Dr. R. Pišot (head of institute)	Welcome	0:30
2. Traffic accident statistics		**09:30**
Mr. K. Parkkari *Finnish Motor Insurers' Centre (FI)*	Bicycle accident data in different statistical databases	0:20
Dr. C. Orsi, Prof. D. Otte, Ms. A. Stendardo, Dr. C. Montomoli & Dr. A. Morandi *University of Pavia (IT) & Hannover Medical School (DE)*	Accident configurations and injuries for bicyclists based on German In-Depth-Accident-Study	0:20
Dr. M. Dodič Fikfak *University Medical Centre (SI)*	Head injuries among Slovenian bicyclists	0:20
Mr. J. Rotar *Slovenian Cycling Network (SI)*	National Strategy for increasing bicycle traffic safety	0:20
Coffee break		10:50
3. Traffic psychology		**11:20**
Prof. Dr. D. Shinar *Ben Gurion University of the Negev (IL)*	Enhancing bicyclist's conspicuity with an apparent motion display (phi phenomenon)	0:20
Dr. I. Walker *University of Bath (GB)*	Risk-taking	0:20
4. Impact protection		**12:00**
Prof. Dr. N.J. Mills *University of Birmingham (GB)*	Impact engineering for improved helmet safety	0:20
Dr. C. Deck & Prof. Dr. R. Willinger *Université de Strasbourg (FR)*	Model based head injury criteria for new standard tests and advanced helmet optimization	0:20
Lunch break		12:40

5. Ergonomics of thermal aspects		**13:40**
Dr. G. de Bruyne *Lazer Sport (BE)*	Heat loss of the human head under bicycle helmets	0:20
Prof. Dr. I. Mekjavić *Institute "Jožef Stefan" (SI)*	Sweating thermal head manikin	0:20
Dr. R.M. Rossi, Dr. S. Annaheim, Dr. C.P. Bogerd *Empa (CH) & University of Primorska (SI)*	Radiant heat gain and bicycle helmets	0:20

Coffee break		14:40

6. Outlook and plenary discussion		**15:10**
Mr. C. Woolsgrove *European Cyclists' Federation (ECF) (BE)*	European Cyclists' Federation, bicycle helmet legislation and public health	0:20
Ms. V. Marinko *Slovenian Traffic Safety Agency (AVP) (SI)*	Safety in numbers and the AVP's vision on improving bicycle traffic safety and the role of helmets	0:20
Prof. Dr. N. Haworth *Queensland University of Technology (AU)*	Helmet safety issues under mandatory universal legislation	0:20
Dr. C.P. Bogerd *University of Primorska (SI)*	Plenary discussion on improving bicycle traffic safety and the role of helmets	0:20

7. Closing		**16:30**
	Closing	0:10

Abstracts

The order of the abstracts is equal to the order of presenting at the present symposium. Not all abstracts could be included in this book of abstracts.

Accident configurations and injuries for bicyclists based on the German In-Depth-Accident-Study

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Introduction

Road traffic deaths, disabilities, and injuries are a major global public health issue. Vulnerable road users play an important role in this context: in EU countries, 20-40% of all journeys are travelled by bicycle or on foot; of all traffic fatalities, the proportion of bicyclist fatalities is about 6% and the proportion of pedestrian fatalities is about 17%. Motor vehicles (cars, lorries, and buses) account for over 80% of vehicles striking pedestrians and cyclists (European Commission, 2012).

Compared to cars, bicycles are less stable, less visible and offer less protection to the rider who hits the hard, non-deformable structures of passenger cars and trucks and suffers the most severe consequences. So, in order to understand which are the most dangerous situations for bicyclists, attention on the characteristics and types of accident involving bicycles has to be paid.

Objectives

To evaluate which are the most common types of accidents involving bicycles and to compare the frequency of injuries.

Methods

All the bicycle riders involved in an accident that occurred in the years 2000-2010 in the areas of Dresden and Hannover stored in the GIDAS (German In-Depth Accident Study) database were analyzed. All the accidents were collected using an in-depth approach and reconstruction methodologies (GIDAS, 2012).

The injury situation was described according to the scientific abbreviated injury scale AIS (American Association of Automotive Medicine, 2012). The whole bodily injury severity is classified as the maximal severity of all injuries of the body (MAIS=maximum AIS). A MAIS >= 3 was considered as a “severe injury”.

Results

In total, 4'928 bicycle riders were analyzed. In the majority of the accidents (63.8%), the bicycle impacted with a passenger car; 13.6% of cases were single accidents. In the other cases the bicycle impacted with another bicycle (11.0%), a truck (5.0%), a bus or tram (1.6%), or a motorcycle (1.2%).

The percentage of people injured was more than 97% among bicyclist who impacted with a passenger car, a truck, a bus or tram, followed by single accidents (93.3%), motorcycle (85.7%), another bicycle (67.2%), a pedestrian (51.4%).

Ten most frequent configurations represent around 60% of all accidents. The most frequent accident type was a "conflict between a non-priority car and a bicyclist with priority coming from a bicycle path" (19.8% of accidents). In this accident type, 99.5% of bicyclists are injured and 3.0% are severely injured. Among the other nine most common accident types, the most dangerous are "conflict between a car and a bicyclist coming from a parallel bicycle path who is turning onto or crossing a road", "single accident on a straight road (without influences of road width or lateral gradient)", "conflict between a bicycle and a car: a non-priority vehicle and a priority vehicle coming from the right, which is not overtaking" (more than 8% of bicyclists severely injured).

Conclusions

More attention must be paid to improve the bicyclist's visibility and conspicuity. Educational intervention appears as a priority, not only addressed to bicycle riders but also to other vehicles drivers.

References

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http://ec.europa.eu/transport/road_safety/specialist/knowledge/pedestrians/index.htm
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American Association of Automotive Medicine (2012). http://www.aaam1.org/ais/

National strategy for increasing bicycle traffic safety

Rotar J

Slovenian Cycling Network, Maribor, Slovenia

Introduction

The National bicycle safety strategy 2012-2021 is the first document in Slovenian history which professionally deals with the causes of accidents and provides a wide range of measures to improve bicycle safety in traffic. They follow the guidelines of the National program for Road Traffic Safety 2012-2021.

The strategy sets out some basic characteristics of cycling in Slovenia. Overview of the cycling population shows the different groups of riders and highlights their specific characteristics and needs. Strategy pays special attention to road traffic infrastructure as an element of safety, which gives examples of good and bad practices of road design. At the same time it puts forward suggestions of smart measures on this field which are already established abroad and would be based on positive experiences in a meaningful transfer of Slovenia. In this strategy we did not forget to mention either the scope of cooperation between different actors and levels of review of their operation.

In assessment of the situation of bicycle traffic safety we analyze different classifications of accidents, analysis of the causes and consequences of accidents, and analysis of the period of the year and time of day. The data suggest that cyclists are involved in 2% of all traffic accidents in Slovenia. Their share in fatal accidents is 7%, while it is 13% in accidents with serious injuries. This confirms the fact that cyclists are a very vulnerable group in traffic.

The ambition of the national strategy is to improve the safety of bicycle traffic by 2021 and to improve basic cycling safety in traffic, especially taking in account the expected growing proportion of cyclist in the next decade in Slovenia. The long-term goal is linked to vision zero, which means zero fatalities and zero serious injuries resulting from traffic accidents in Slovenia.

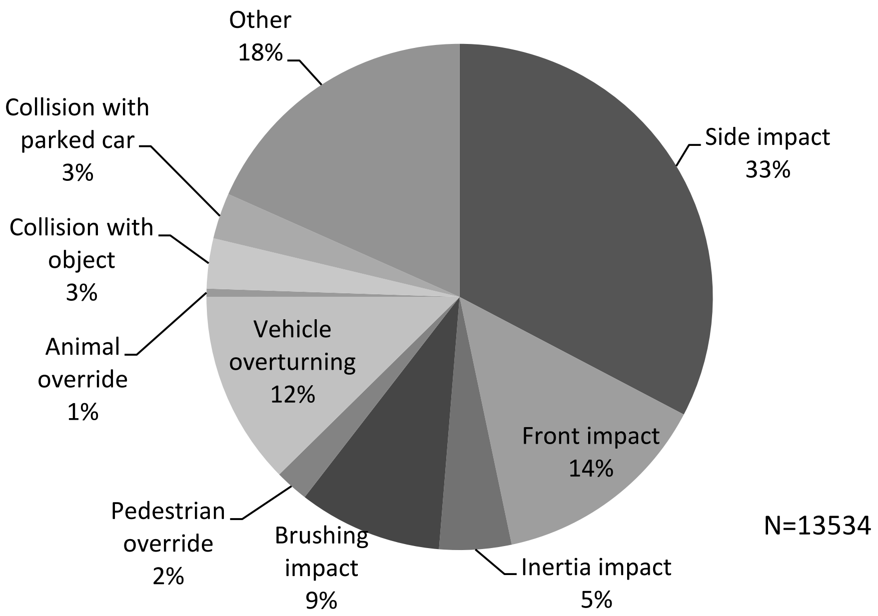

Fig 1. *Types of cycling accidents in Slovenia between 2001 and 2011.*

The action plan is concentrated on different sections: infrastructure, management, monitoring, technical equipment, education, research, communication, law and finances. The purpose of a national strategy is to improve the safety of bicycle traffic in Slovenia and to provide guidelines for further activities in this area in coming years.

Given that this document is the first of this kind in Slovenia, during its creation it took a lot of ingenuity. Due to the lack of some key data, which are not collected in Slovenia, its comparativeness with similar studies abroad is questioned. Correlations between the number of cyclists and road safety, could not be proved, but may instead be caught in the trap and lead to some erroneous conclusions. Because of this the strategy is also designed to avoid unnecessary mistakes and to focus our efforts for improvement of cycling safety into the right direction.

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Enhancing bicyclist's conspicuity with an apparent motion display (phi phenomenon)

Shinar D*

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While there is ample research on the causes of motor-vehicle accidents, ad some research on the causes of motorcycle accidents, data on the causes of bicycle accidents are rare. In one study conducted in Japan, one of the three major causes listed was the smaller visual size of the bicycle relative to a car, inducing a situation "where the driver was hard to find the bicycle, and actually caused the accident." (sic) (Yasunori et al., 2006). In an early analysis of the causes of motor-vehicle crashes in the U.S., Hunter et al. (1995) noted that "a great proportion of car–bicycle accidents includes cyclists who come from a direction inconsistent with the normal car traffic flow". These types of findings suggest that a significant problem of bicyclists is their poor conspicuity and visibility. While visibility refers to the detectability of an object that is being searched for, conspicuity refers to the extent that the object "jumps" into consciousness when it is not necessarily being searched for. The relative lower frequency and smaller size of bicycles compared to cars suggest that these are significant problems contributing to their crash involvement. In a previous study on motorcycle conspicuity and visibility we showed that both can be improved with innovative lighting displays, involving a light display on the helmet that creates an illusion of a moving light (apparent movement – Phi phenomenon) (Gershon and Shinar, 2010).

The present study is still at the design stage. In this study we plan to enhance bicyclist's conspicuity by installing matched flashing red lights on the helmet and on the back of the seat or just below the seat of the bicycle. The flashing will be synchronized so as to create an apparent vertical movement of a spot of light between the two endpoints to anyone approaching the cyclist from behind. Compared to the motorcycle study where the span of movement was only 15 cm, here the span of movement will be 60-80 cm, thus enabling a heightened perception of the movement from a much greater distance. In a similar fashion synchronized forward-facing white lights will be placed on the helmet and the center of the handlebar.

The study method will be based on the motorcycle study and will involve creating video segments from riding in the real world. The video segments will be shown to participants in the laboratory to assess the probability and speed of detection of the cyclist while approaching it from various distances.

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Yasunori M, et al. (2000). The effect that characteristics of bicycle give to the cause of traffic accident. Proceedings of the JSAE Annual Congress, p. 5-8.

Risk-taking

Walker I*

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Bicycle helmets are one part of a complex traffic system that is inevitably based around human perceptions and behavior. There has been much speculation about whether bicyclists might change their behavior, and take greater risks, when they feel protected by a helmet. Such suggestions are usually couched in terms of risk homeostasis models. More recently, there have also been suggestions that other road users respond to a bicyclist's helmet by changing their behavior. This presentation reviews some of the key evidence for and against the ideas that rider and non-rider risk-taking behavior might be affected by the presence of a bicycle helmet. It also considers the cause and effect of bicycle helmets and casualty figures, and examines the idea that reduced casualty figures for helmet-wearing bicyclists might simply be an epiphenomenon of risk-averse personality traits.

Impact engineering for improved helmet safety

Mills NJ*

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Introduction

Research experience on finite element analysis (FEA) modeling of bicycle helmet oblique impacts was combined with the results of reconstructing 240 UK cycle crashes, causing severe head injuries to cyclists who did not wear helmets. Crashes were classified as either

a) No head contact with a vehicle, e.g. a car makes a glancing impact with one wheel of a bicycle, or the car mirror contacts the bicycle handlebar end when overtaking. The cyclist falls to the road and strikes his head.
b) Head contact with a vehicle e.g. a cyclist crosses a road as high speed car approaches, the cyclist's head often hits and fractures the windscreen.

Impact sites: medical evidence and performance limitations

Skull fracture patterns or scalp bruise locations often indicate the head impact site better than the skull fracture site. Long, linear fractures through the vault do not pinpoint the impact site. Fractures through the petrous temporal bone are caused by blows at the rear of the head, or high up at the sides, due to the stress-concentrating effect of the ear opening. CT scans may reveal fragments of bone at the impact site.

Impact testing (Depreitere et al, 2007) using a flat faced pendulum to hit a site low at the side of a helmet worn by a cadaver, suggested that helmets perform poorly for such impacts. This was challenged using FEA simulations (fig. 3b) (Mills, 2008). In a lateral fall to the road, shoulder contact would occur first, hence the impact site would be relatively high, in a region covered by a helmet, and tested in EN 1078 (fig. 1a).

Research impacts using isolated headforms suggest that helmets perform poorly for sites low at the rear. Cyclists cannot break falls to the rear by throwing out their limbs, and vehicle contact with the bicycle rear wheel is unexpected. However, in a typical riding posture (fig. 3b), the neck is extended to look ahead, and the low rear of head is protected from road contact by the back, assuming that the rider's body position does not change in the fall.

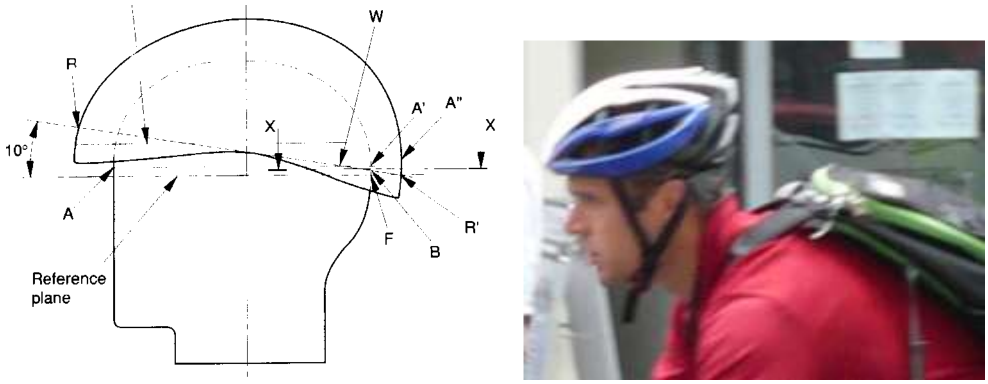

***Fig 1**. a) impact sites in EN 1078 lie above the line RR', b) when riding a sport bicycle, the neck is extended to see ahead, and low sites at the rear cannot be hit.*

Fall velocity

Crash reconstructions often apply Newtonian mechanics for the free fall of a rigid body to the head. The vertical component of impact velocity V_V for a fall from zero V_V at a height h, under the acceleration of gravity g is $\sqrt{(2gh)}$. This is a major assumption for a person falling from a bicycle, and the real V_V is probably smaller. Motion analysis (Bretting et al, 2010) of a stuntman somersaulting over the handlebars when the front wheel sudden stopped, found V_V in the range 3 to 4 m/s, compared with a free fall V_V = 5.4 m/s. The rider's rotation did not increase V_V over the free fall value. Hence the 5.4 m/s used in EN 1078 impact tests adequately simulate falls to the road. For oblique impact tests with a free headform (Mills and Gilchrist, 2008a,b) the peak linear headform acceleration was independent of the horizontal component of impact velocity. When a cyclist falls to the side, his initial potential energy is converted into the kinetic energy of vertical motion, lateral motion, and rotation. Hence again V_V is likely to be less than $\sqrt{(2gh)}$. Motion analysis of falls to the side would be of interest.

The EN 1078 bicycle helmet standard

The EN 1078 standard affects helmet design, so its impact tests should be critically compared with real crashes. The test equipment has to be durable, repeatable, and of moderate cost. The vertical drop tests fail to simulate helmet rotation on the head during an oblique impact. FEA shows that the helmet contact area is large and it moves across the helmet during an oblique impact. The range of impact sites (fig. 1a) was influenced by the limitations of helmets in 1997, and ignores frontal sites frequently hit in crashes. Post 1997 bicycle helmets have more and larger ventilation holes, and adjustable headbands to 'fit' a single size liner to the range of head sizes.

An increase in the impact test velocity would force helmet liner foam to be thicker. Such helmets might not be acceptable in countries where helmet wearing is not legally required. In the UK legal system, non helmet wearers may receive reduced damages against a motorist if the impact speed is higher than that in EN 1078, or the head impact site is below those tested.

Helmet positional stability

The retention system effectiveness test is derived from those used to limit forward rotation of motorcycle helmets on the head, in spite of bicycle helmets having 20% of the mass, and cyclists not undergoing high body deceleration against a fuel tank. The retention strap junction lies below the wearer's ear (fig. 2a), so below the centre for helmet rotation. Rotation is restrained if the webbing straps attach to the foam liner near its lower edge, ahead of and behind the junction, and the strap is tight under the chin. If the front strap attaches vertically above the 'Y' junction (fig. 2b), rearward helmet rotation is easy. Helmets should not be tipped back, with the strap loose under the chin (fig. 6a). EN 1078 should contain a test to limit rearwards helmet rotation.

***Fig 2**. a) cyclist in London, b) front chin strap runs vertically to mount on helmet*

Finite element analysis (FEA)

FEA requires detailed knowledge of helmet geometry, the position of retention straps relative to the headform, and the friction coefficient at the head/helmet interface. Models for compressible foams must include the foam yield criterion under multiaxial stresses. Fig. 3a shows, for a frontal impact with the cyclist's head moving forward horizontally at 10 m/s, a helmet protects a site lower than those tested in EN 1078. More information is needed on: the range of head impact velocities in real falls, crash reconstruction data for cyclists wearing helmets, and head injury tolerance.

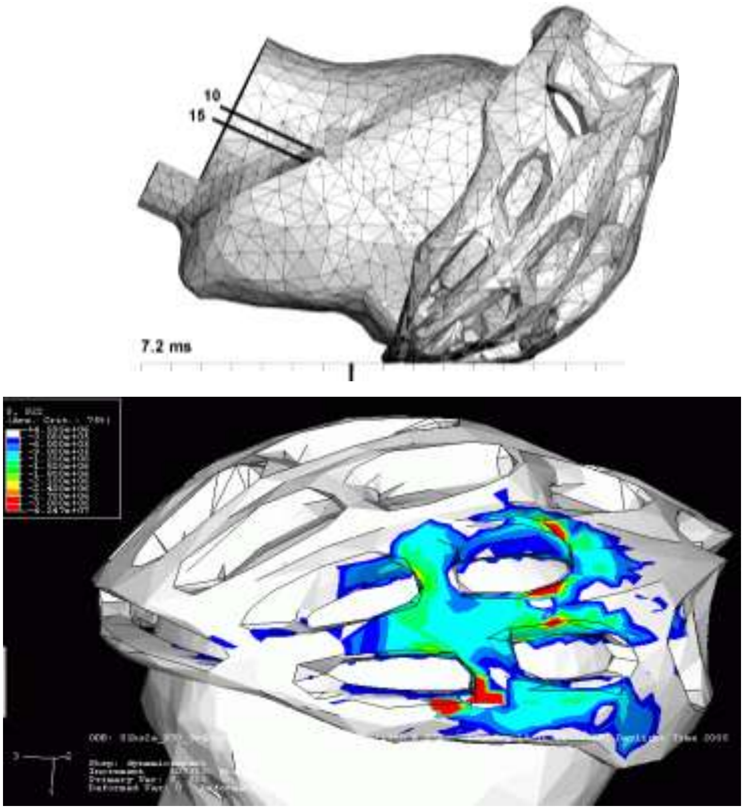

***Fig 3**. FEA predictions the helmet shape in oblique impacts at a) frontal, b) lateral sites*

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Model based head injury criteria for new standard tests and advanced helmet optimization

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Introduction

This paper presents an original full validated numerical human head finite element (FE) model. Validation shows that the model correlated well with a number of experimental cadaver tests including skull deformation and rupture, intra-cranial pressure and brain deformation. This improved numerical human head surrogates has then been used for numerical real world accident simulation. By correlating head injury type and location with intra-cerebral mechanical field parameters, it was possible to derive new injury risk curves for injuries as different as subdural haematoma and neurological injuries. Illustration of how this new head injury prediction tool can participate to the development of new standard tests as well as head protection system optimisation is also provided.

Head injury prediction tool for helmet optimization

Kang et al., in 1997 developed the Strasbourg University Finite Element Head Model (SUFEHM). The main anatomical features modeled were the skull, falx, tentorium, subarachnoid space, scalp, cerebrum, cerebellum, and the brainstem. Globally, SUFEHM model consists of 13208 elements. Its total mass is 4.7 kg, and an overview of the model is given in Fig. 1.

In order to derive model based head injury criteria, a total of 59 real world head trauma that occurred in motorcyclist, American football and pedestrian accidents were reconstructed with SUFEHM by Deck et al (2008). Three tolerance limits to specific injury mechanisms have been computed for a 50% risk. Results show a maximum Von Mises stress value of 28 kPa for moderate diffuse axonal injury (DAI) and 53 kPa for severe DAI, a maximum cerebrospinal fluid (CSF) strain energy of 4.9 J for subdural hematoma (SDH) and a maximum strain energy of 0.86 J for skull fracture.

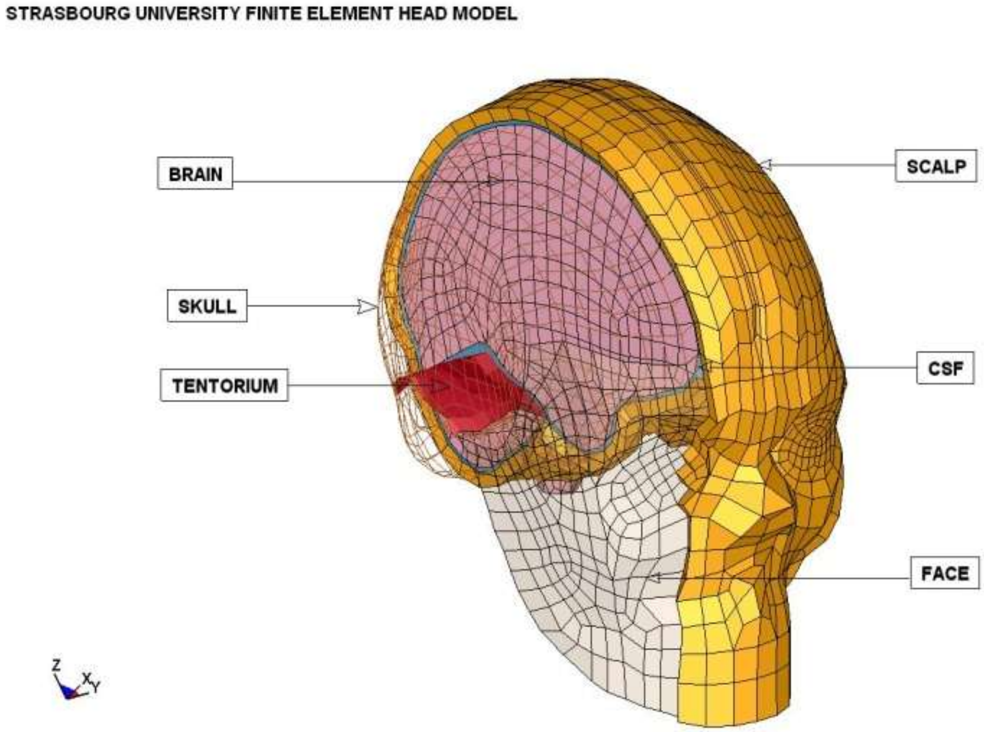

***Fig 1**. Section through the Strasbourg University Finite Element Head Model*

Based on the previous head injury criteria, a new helmet evaluation and optimization method is suggested. In the proposed approach the experimental linear and rotational head acceleration constitutes the inputs which will drive the head FE model, in charge of the latter to compute the injury parameters related to skull fracture, sub dural haematoma and neurological injury. By this methodology it will be possible to predict head injury risk means a coupled experimental versus virtual evaluation and optimization procedure as illustrated in fig. 2.

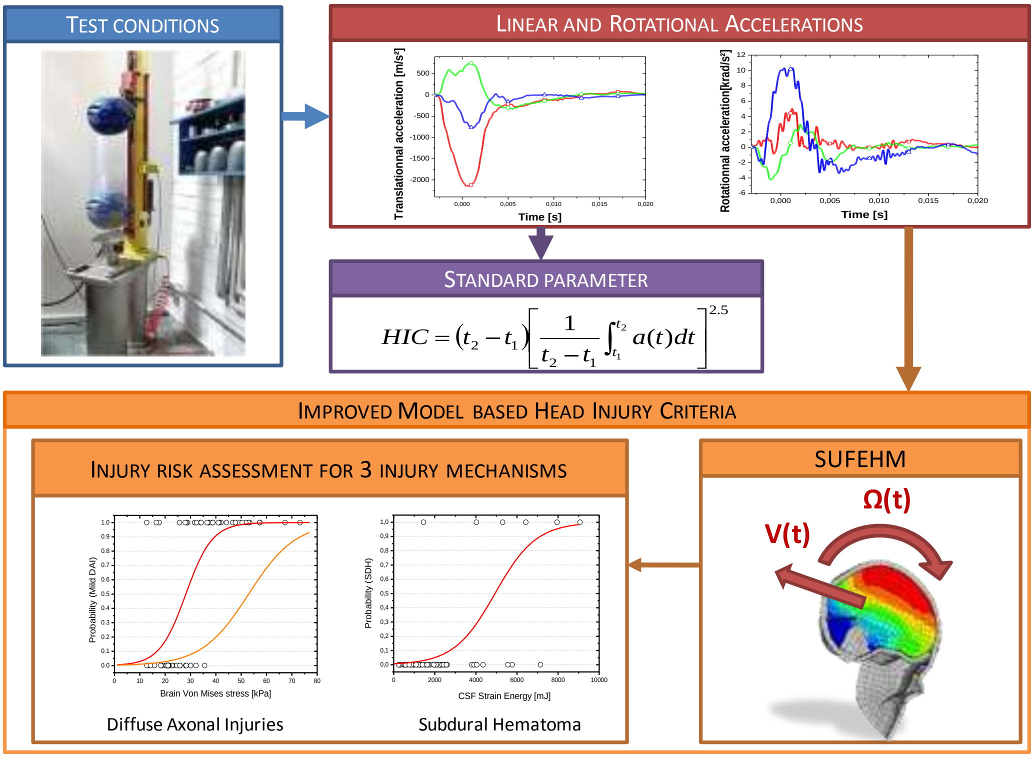

Fig 2. *Illustration of the coupled experimental versus virtual helmet test method*

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Heat loss of the human head under bicycle helmets

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Cycling is very popular. It is healthy and environmentally friendly. Unfortunately, about eight times more cycling fatalities occur compared to car fatalities per travelled kilometer (Koornstra et al., 2003). Head injuries are the most frequent cause of death in about 69% of the cycling fatalities (Fife et al., 1983; Wood et al., 1988; Ostrom et al., 1993). Current bicycle helmets reduce approximately 60% of severe head injuries in cycling fatalities. Unfortunately, bicycle helmets are not always popular. In Belgium, less than 5% of the cyclists wear one. Cyclists refuse to wear bicycle helmets due to peer pressure, lack of style of the current bicycle helmets and discomfort, especially thermal discomfort (Howland et al., 1989; Sacks et al., 1994; Brühwiler et al., 2006; Villamor, et al. 2008).

In this research it was shown that the air temperature (fig. 1a) between head and bicycle helmet increases with approximately 3°C at 20°C from the front of the head towards the rear and that sweat production (fig. 1b) was on average twice as high at the rear of the head, compared with the front (De Bruyne et al. 2008). Using object studies (fig. 1c), it was shown that only a fraction of the fresh air in front of a bicycle helmet enters it (De Bruyne et al., 2012). At best, only 17% to 18% of the fresh air in front of a bicycle helmet reaches the front of the head when people are cycling at low speed (3 ms^{-1}). Fresh air concentration at the rear of the head can even diminish to 1% compared to the fresh air concentration in front of a bicycle helmet. These results were unexpected, but were confirmed using a mechanistic model (Desta et al., 2008). The studies showed that there is a large potential for improving the ventilation efficiency of bicycle helmets. As a result, a new kind of bicycle helmet concept is proposed with on average 16% more ventilation efficiency, while having three times less vents compared with the helmet it was optimized from. Finally, first steps are taken towards an active ventilated bicycle helmet that may allow designing helmets with even fewer vents (De Bruyne et al., 2010).

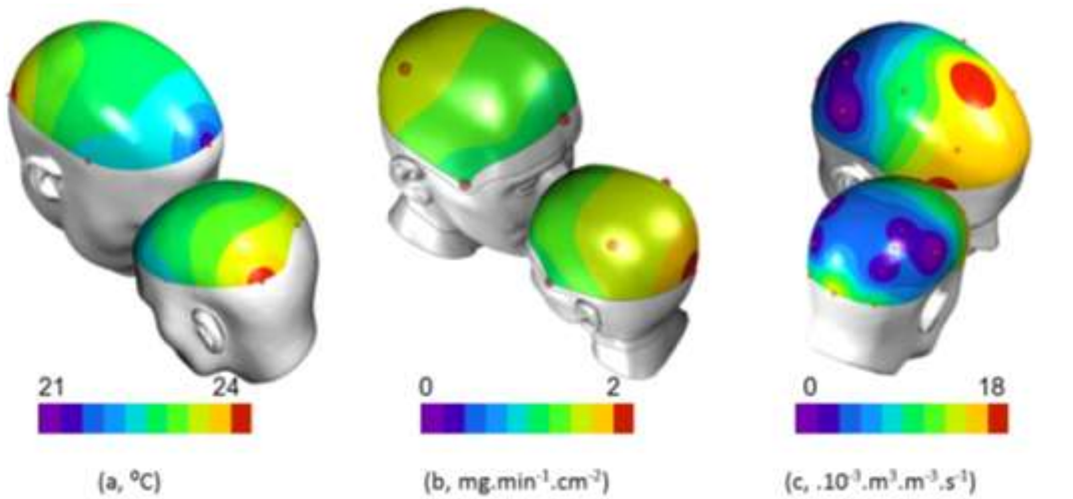

***Fig 1**. Interpolation of air temperature (a) measured at five locations, sweat production (b) measured at four locations and ventilation efficiency (c) measured at 13 locations under a bicycle helmet. Subject tests and manikin head test were performed using the same helmet.*

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Radiant heat gain and bicycle helmets

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Introduction

Heat and mass transfer of the human body occurs through conduction, convection (i.e. ventilation), evaporation and radiation; depending on environmental conditions. Under sunny conditions a body will be warmed by radiant heat gain. In fact, radiation is an important variable for outdoor thermal comfort (Kenny et al. 2008) and during exercise in the sun (Nielsen et al. 1988). Particularly the head has been ascribed as an important sensor for human thermal comfort (Arens et al. 2006, Cotter & Taylor 2005) and subjects generally feel more comfortable with a cool head region (Zhang et al. 2010). Protection of the head during working or leisure reduces thermal comfort. Hence, the main reason for not wearing a helmet is thermal discomfort caused by the headgear (Hickling, 1986). However, headgear might impair heat and mass transfer but could also reduce radiant heat gain, thereby resulting in a more favorable situation compared to the nude head.

NUDE *PRH* *CW* *CB*

Fig 1. *Headgear evaluated under different radiant heat gain conditions in Bogerd et al. (2008).*

Headgear and radiant shielding

A thermal manikin headform (Brühwiler 2003) was used by Bogerd et al. (2008) to estimate the net heat transfer from a human head while wearing a headgear (fig. 1). Headgear strongly reduced the radiant heat gain with 80% to 95% compared to the nude headform (fig. 2). The effect of hair on net heat transfer was considerable as shown by adopting a wig on the nude manikin head form and also has been shown in a human subject study (Coelho et al. 2010). Most of net heat transfer occurred through the face section. Therefore, the face section has to be considered as well when investigating radiant heat transfer. Brühwiler (2008) investigated the role of the forward and upper vents and the visor by imposing radiant heating of 9.3 W. Heat gain distribution for the nude manikin was 43% to the face and 57% to the scalp. The investigation of 26 helmets without visor revealed a rejection of 50-75% of the radiant heat gain. With the visor mounted, helmets rejected 65-85% of radiant heat gain. However, large variations have been observed among helmets with regard to radiant heating of the scalp.

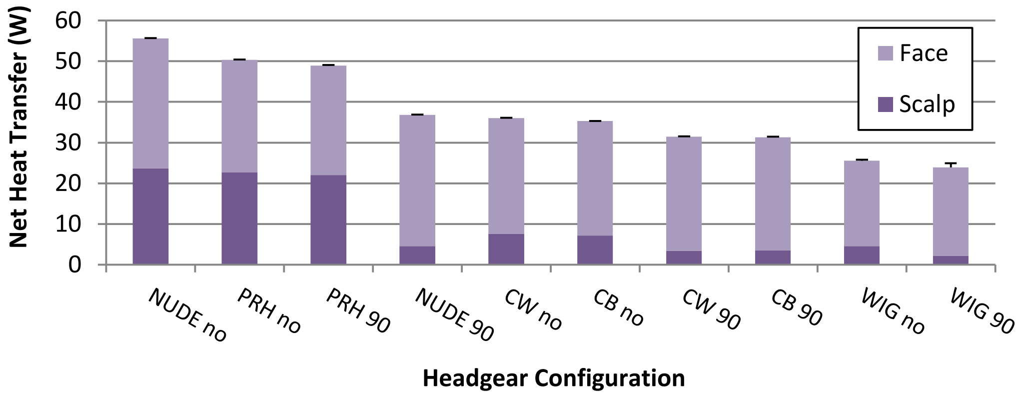

Fig 2. *Average net heat transfer of different headgear and different radiant heat gain conditions. NUDE is the nude headform, PRH is a prototype rowing headgear, CW is a white cap and CB is a black cap. "no" indicates the absence of radiant heat gain. Data is taken from Bogerd et al. (2008).*

Conclusions

Helmets available today show a wide variation with regard to radiant heat gain (Brühwiler 2008) and ventilation performance (Brühwiler et al. 2006). Therefore, the effect of visor on radiant shielding and vent construction to optimize net heat transfer needs further investigation to gain a more systematic understanding of bicycle helmet design. Finally, this knowledge should lead to an optimized bicycle helmet design regarding heat and mass transfer.

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European Cyclists' Federation, bicycle helmet legislation and public health

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Introduction

Bicycle helmets were first developed in the 1970's along with other bicycle equipment initially to provide protection from minor crashes. Since then they have been championed as a possible legislative tool to increase safety and eliminate head injury casualties.

However there is conflicting evidence concerning the efficacy of helmets to withstand collisions, particularly with motorized traffic. But there is also evidence that legislating for the mandatory use of bicycle helmets can in fact decrease numbers of cyclists, mitigating the large health benefits of cycling.

It is this relationship between the effectiveness of legislation versus the impact on public health of a decrease in cycling numbers following helmet legislation that the presentation wishes to explore.

Bicycle helmets as a public health issue

In cities and countries where legislation has been introduced there is evidence suggesting that this has had a harmful effect on the numbers of cyclists; Australia being the classic example.

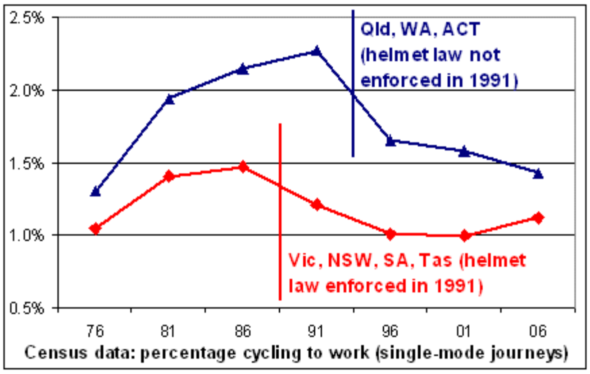

***Fig 1**. Percentage cycling to work Australia 1976 - 2006, Helmet law 1991 (AUS Census Data).*

In all states, cycling to work increased from 1976-1986 but, depending on when the helmet law was introduced, fell afterwards from which it still has not recovered.

In fact there is also evidence that suggests that despite helmets being mandatory the risk of head injuries have not fallen. Head injuries and non-head injuries in most Australian states before and after the legislation was introduced showed identical patterns of progress, therefore it is debatable that legislation has led to any decrease in head injury.

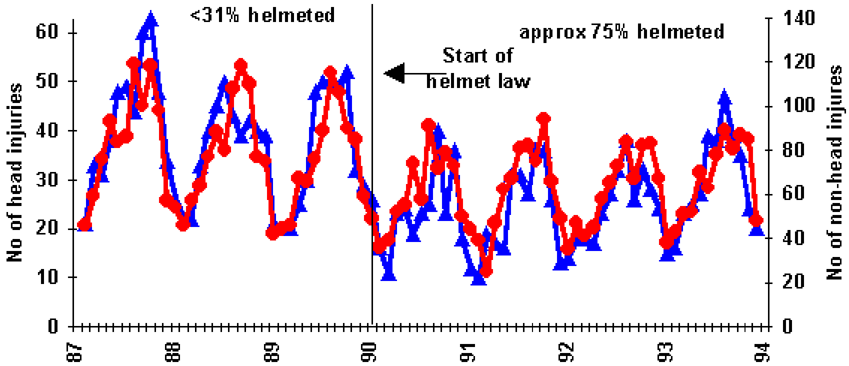

***Fig 2**. Incidence head/non-head injury before and after helmet law Victoria Australia (Carr 1996).*

Cost-Benefit of helmet legislation

The presentation will explore the risks (costs) of cycling and the benefit (health) of cycling and will show that helmet legislation may decrease cycling numbers at the expense of the benefits while raising the risks.

Risks of Cycling

Cycling is a low risk activity; per kilometre travelled it has a similar risk of fatality as walking. This is an important point to remember as in many European countries cycling is seen as an everyday normal activity.

Road (Total)		0.95
Motorcycle/moped	13.8	
Foot	6.4	
Cycle	5.4	
Car	0.7	
Bus and coach	0.07	
Ferry		0.25
Air (civil aviation)		0.035
Rail		0.035

***Fig 3**. Deaths per million person kilometres (ETSC, 2003).*

Health benefits of cycling

Cycling is also a healthy activity which can have a major impact on public health. A study (De Hartog et al., 2010) which looked at air pollution, accidents, physical activity, comparison of life years and factors determining life years found that "…the well-documented beneficial effect of increased physical activity due to cycling resulted in about 9 times more gains in life-years than the losses in life years due to increased inhaled air pollution doses and traffic accidents."

Given the reduction in cycling numbers after legislation, De Jong (2011) has shown that even if helmets were 100% effective at preventing ALL cycling injuries (i.e. not just head-only injuries) there would be a net increase in early deaths (for example due to physical inactivity etc.) if there were more than one person deterred from cycling for every 21 who continue.

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Helmet safety issues under mandatory universal legislation

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Introduction

Mandatory universal helmet legislation was introduced in most parts of Australia in about 1990. This paper describes the legislation and the Australian Standards for bicycle helmets. It presents information on wearing rates and outlines challenges in demonstrating the effectiveness of the legislation and pressures to amend the legislation.

The legislation

Part 15, Section 256 of the Australian Road Rules states that the rider of a bicycle must wear an approved bicycle helmet securely fitted and fastened on the rider's head, unless the rider is exempt from wearing a bicycle helmet under another law of this jurisdiction. There are some exemptions for medical reasons or for paying passengers on a 3 - or 4-wheeled bicycle. The legislation applies on all roads (including shoulders and footpaths) and any area open to the public for use by cyclists or animals or for parking (except in the Northern Territory). The fine for not wearing a helmet is $100-$150 and most fines issued to bicycle riders are for failing to wear a helmet (Courier Mail, 2012; TORUM, 2010; VicRoads website).

The bicycle helmet standard

Every helmet sold in Australia must carry a sticker or label certifying it meets AS/NZ 2063:2008. There are seven tests in the standard, including a pointed anvil being dropped onto the helmet to simulate it hitting a kerb or angular penetration from a car. Fines of up to $1.1 million plus product recalls can be imposed on an Australian business for selling non-compliant helmets. Helmets purchased online may not meet the standard and their use is illegal without the sticker.

Wearing rates

Observational surveys showed large increases in helmet wearing when the legislation was introduced (Cameron et al., 1992; Finch et al., 1993). Two recent studies observed more than 97% of commuter cyclists wearing helmets (Haworth & Schramm, 2011; Johnson et al., 2011). Wearing rates are lower in crashes, with riders in 12% of police-reported bicycle crashes (Schramm et al., 2010) and between 15% (Sikic et al., 2009) and 32% of killed riders (ATSB 2006) not wearing helmets. Helmet wearing rates are lower for riders aged 20 and under in observational, injury and fatality data. Non-fastening of helmet straps is an issue, particularly among young males.

Challenges in demonstrating helmet law effectiveness

A range of challenges have arisen in demonstrating the effect of helmet laws in Australia. These include incomplete reporting of on-road bicycle crashes to Police, no requirement for reporting non-fatal off-road crashes, no recording of helmet use in routine hospital data sets, lack of comprehensive riding data and lack of a clear comparison group.

Pressure to amend legislation

There is pressure to amend the helmet legislation to restrict its scope. Public health researchers argue that the helmet requirement reduces riding and that this has resulted in health disbenefits from chronic disease which outweigh the health benefits of reductions in head injuries. Low usage rates of public bicycle hire schemes in Melbourne and Brisbane have been blamed on the helmet requirement. Certainly, usage rates in Brisbane increased dramatically when helmets were provided with some of the public bicycles.

Conclusions

The introduction of mandatory helmet wearing legislation has increased wearing rates and reduced head injuries. The initial effects of reductions in cycling seem to have worn off, but challenges remain.

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