Chapter 6. Countermeasures promoting the use of personal protective equipment

Head injuries are the most critical injuries affecting powered two-wheeler (PTW) riders. This chapter presents the safety value of the helmet which is the primary equipment to protect the rider. It also describes other protective equipment, including protective clothing, airbag jackets, high visibility clothing and neck braces.

Introduction

The proper use of helmets has strongly proved its efficiency to reduce injuries. A helmet is therefore the primary equipment to protect the rider. Other recommended protective equipment includes protective clothing (such as protective gloves, boots jackets and pants, often equipped with limb protectors), airbag jackets and neck braces.

Helmets

A helmet prevents or reduces head injury. The SWOV factsheet on helmets (SWOV, 2010) describes the four basic components of a helmet: outer shell, inner shell, protective padding, and chin strap. Furthermore, most types of helmet also have a visor. The task of the hard outer shell, usually made of fibre reinforced composites or thermoplastic, is to prevent objects from penetrating, and to spread energy. The task of the soft inner shell, usually made of polystyrene foam in various densities, is to absorb the collision energy slowly and to spread it over a large area of the head. The protective padding, often made of polyurethane, ensures comfort of wear. The chin strap ensures that the helmet remains on the head no matter what happens. The helmet wearer's vision is guaranteed by the hinged visor. The shape of the helmet reduces wind noise to acceptable proportions, although turbulence can still raise the sound level.

There is a wide diversity of standard helmets, including Open-Faced, Full-face and modular helmets. These offer differing levels of protection, albeit there is no requirement for a specific type of helmet for specific use.

Helmet standards

Motorcycle helmets sold in the United States are required to meet the federal standards set forth by the Department of Transportation (FMVSS 218). In addition to these federal required standards, the Snell Memorial Foundation has set up a series of voluntary standards for motorcycle helmets as well. The tests in the two sets of standards are different in both design and specifications for the results of the testing. Riders should choose a helmet that is DOT certified and many riders also choose to wear a helmet that has the additional Snell certification. A helmet that meets multiple safety standards provides more safety benefit to the rider. The Economic Community of Europe (ECE) is currently the most commonly used motorcycle helmet safety standard internationally, as compliance with ECE 22.05 is required by over 50 countries worldwide. One of the advantages is the requirement for mandatory batch testing of helmets before they are released to the public. This means that the quality of the helmet in meeting the ECE 22.05 standard is assured by the compulsory sample testing of every production of helmets before they leave the factory.

The Safety Helmet Assessment and Rating Programme (SHARP) was established by the UK Department for Transport in 2007, as part of the Government's commitment to reduce motorcycling casualties. SHARP's objectives are twofold:

- To provide clear advice on how to select a helmet that fits correctly and is comfortable.
- To provide consumers with clear, impartial and objective information about the relative safety of motorcycle helmets through a 1 to 5 star safety rating.

Each model of helmet rated is subjected to 32 impact tests and, to date, 304 helmet ratings have been published.

Certainly, the protective effects of the helmet can still be improved. Perhaps this requires adapting the test procedure requirements so that advanced materials and constructions can contribute optimally. Of course it is important to aim for the highest quality and protective effect of helmets. In any case, users should be aware of the technical performance of their helmets and quality should be assured.

Affordability is sometimes claimed as an excuse not to wear a helmet, however this cannot be an acceptable argument, at least in high-income countries, where the cost of a standard helmet is only a very small proportion of the purchase price of a motorcycle, and tiny in comparison with the health expenses and the consequences of a head injury. In lower income countries, the situation might be different, and a solution must be found to offer well protecting helmets at a reasonable price (see also Chapter 9).

Helmets standards should be developed taking into account the various climates in the world: it might be challenging to wear the same helmet in tropical conditions and during the winter in a country with very cold temperatures.

Evidence of effectiveness

Wearing a helmet considerably reduces the risk of head injury in a crash. An international review of 61 studies on the use of a helmet shows that the risk of severe head injury decreases by about 69% when wearing one (Liu et al., 2007). The risk of being killed in a motorcycle crash decreases by about 42%.

Studies have compared the effectiveness of the various helmet types, particularly the integral helmet and the jet helmet. It is clear that an integral helmet with a fixed jaw guard considerably reduces the risk of chin and facial injury. Studies carried out in Taiwan and Australia found no difference between the integral and the jet helmet in causing spinal cord injuries (Lin et al., 2004; O'Connor, 2005).

In a recent study in 70 countries, factors such as helmet non-usage percentage and motorcycle per person ratio were positively associated with motorcycle-related death rates. A simple linear regression model between helmet usage and road traffic death rate has shown that for each 10% increase in helmet usage, one life per million inhabitants can be saved per year (Abbas et al., 2012).

Measures to increase wearing rates

Given the proven effectiveness of a helmet, motorcycle safety could benefit considerably from a nearly 100% wearing rate. This first requires that helmet wearing is mandatory. As mentioned previously, not all OECD countries have a helmet law. Only after such a law is installed can helmet wearing be enforced (see also section on enforcement). In order to increase the acceptability of the helmet law, the enforcement strategies should be complemented with communication campaigns and publicity.

In aiming to increase wearing rates there are a couple of issues to consider. First, not only should wearing be enforced, also *proper* wearing of a helmet should be enforced. When a helmet is worn without a fastened chin strap, the effectiveness of protection in a crash is considerably limited. Therefore it is important to keep the chin strap well fastened, allowing no slack. Especially among moped riders there is a tendency not to wear the helmet correctly.

Protective clothing

The term "protective clothing" refers to garments (i.e. boots, gloves, pants and jackets) that aim to prevent, or reduce, the severity of injuries when a crash occurs. Protective clothing essentially reduces

the risk of abrasion in case of friction with the road surface. It also prevents some piercing injuries and increases the threshold for fractures.

Research has indicated significant benefits from wearing protective equipment. A study undertaken by de Rome et al. (2011) showed significant reductions in injury risk if riders were wearing a range of protective clothing. Riders were significantly less likely (20% to 60%) to be hospitalised if they were wearing jackets, pants or gloves and less likely to incur injury if garments included fitted body armour with greatest reductions for injuries to extremities. Even non-motorcycle boots showed a halving of risk compared with shoes.

The study also showed that 25% to 30% of gloves, jackets and pants designed for motorcyclists failed due to material damage in the crash. While this may indicate the need for improved standards, it may also indicate that the practical limit of the protection available from clothing can frequently be exceeded in a crash. Consistent results were obtained from ACEM (2009) (see Table 6.1).

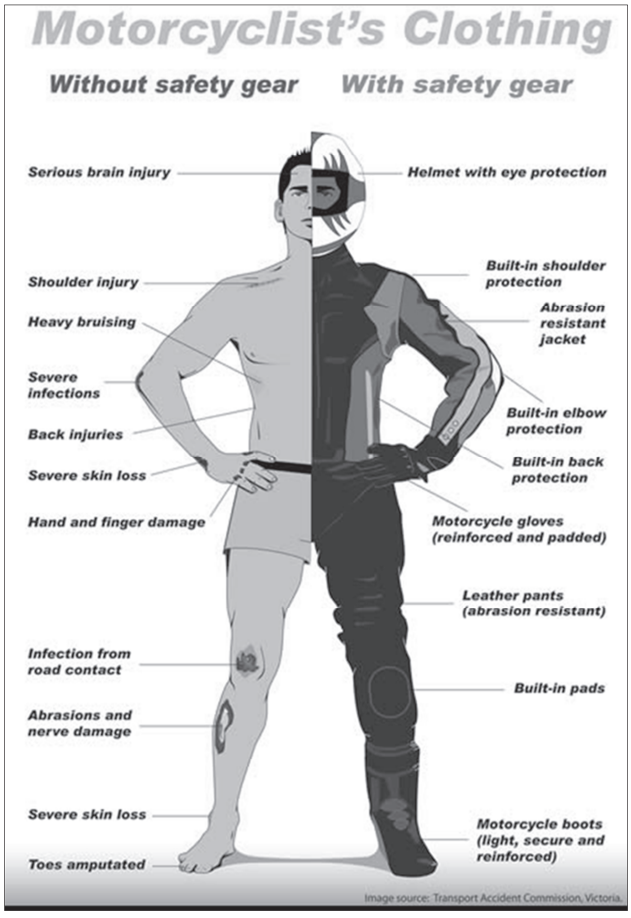
Table 6.1. **Percentage of crashes in which protective equipment contributed to reduced, or prevented, injury**

Protective clothing worn	Percentage (%) of crashes in which coverage was present and contributed to reduced or prevented injury	
	Rider	Passenger
Upper torso	65	49
Lower torso	61	46
Footwear	49	29
Gloves	44	25

Source: ACEM (2009).

There are benefits from the introduction of harmonised standards to support the global product production and distribution. On the other hand, there is a trade-off, if a minimum standard is imposed that results in a price on equipment that exceeds the riders' willingness, or ability, to pay. In particular, the need to increase equipment wearing rates in developing countries may not be supported by a global standard based on the needs of more affluent riders in OECD member states. The European Committee for Standardisation (CEN) has published standards for protective equipment for motorcyclists' protective clothing against mechanical impact.

Figure 6.1. **Protective clothing zones**



Source: Transport Accident Commission, Victoria.

While the introduction of mandatory requirements imposes a cost on riders, and may therefore be subject to significant community opposition, any increase in the use of protective clothing through promotion to increase rider awareness has the potential to provide significant benefits. Elvik and Vaa (2004) have analysed several studies of the impact of protective clothing. Respective injuries are expected to decline between 33% and 50% by use of protective equipment. The benefit-cost ratio was estimated to be 5.3, which makes protective equipment a highly efficient way of reducing the number and severity of injuries.

The publication and distribution of brochures on protective clothing promotion by licensing agencies or at point of sale, supplemented by mass media advertising, form an important part of motorcycle safety strategies.

While research into the benefits of protective clothing is unequivocal, there remain a number of impediments to increased or, eventually, universal use. The first is inconvenience. The most effective protection involves a significant amount of bulky clothing and the time and effort required to use this every time may be a deterrent for riders, particularly in short trips perceived to be of low risk. For example, research by the Victorian Transport Accident Commission (TAC, 2011) indicated that while boots were almost universally worn by recreational riders, they were only worn by 60% of commuters.

This bulk and weight leads to two other factors acting against universal use: heat and comfort. Finally, costs may also be an issue.

Another impediment to promotion and increased use of protective clothing is lack of good consumer information provided to riders about the protective value of the particular item that is being sold. While standards for motorcycle protective clothing were issued in Europe in the late 1990s, few European manufacturers submit their products for testing, circumventing the need for compliance by avoiding any reference to safety or protection in product descriptions.

Further research and development into clothing and equipment with lower weight and improved ventilation should be encouraged. Promotion of the benefits of protective clothing and resulting consumer awareness and demand is likely to be one of the key drivers of this.

Airbag "jackets"

Airbags built into a rider's jacket, or suit, are a recent development in motorcycle safety. These systems involve the same principles as vehicle-mounted airbags where, upon detection of a crash situation, the airbag is automatically deployed to minimise injury to the rider.

Two different mechanisms of airbag jackets exist. The first mechanism of airbags jackets come into effect once the motorcyclist has been thrown from the vehicle. The jacket is connected to the vehicle through a cable, and when this connection is severed (the force of the rider being thrown from the motorcycle uncouples a pin or key in the jacket) the airbag inflates. The second one is based on radio communication between the front wheel and the jacket. When sensors placed in the motorcycle (accelerometers fixed in the front wheel for example) detect a crash (because it reaches a high level of acceleration for example) a signal is sent to the jacket which inflates immediately. The first one will only inflate in the case of a separation between the rider and its engine, thus preventing undesired (and potentially dangerous) inflation; but it will not inflate in case of a crash when the rider and the vehicle are split late in the crash process. The electronic one will prevent the latter case, but must rely on complex (and expensive) technological devices.

The riders will still hit the obstacle with the same force, but they will be protected with a cushion of air surrounding their upper body. Airbag jackets are inflated by a carbon dioxide cylinder built into the jacket, which is less flammable than the gases used to inflate vehicle-mounted airbags.

Airbags jackets, like vehicle-mounted airbags, are passive systems which serve to reduce injury severity. In addition to front-impact crashes, airbag jackets could be effective in a range of loss of control or multiple vehicle crashes where the rider is thrown from the vehicle.

In order to evaluate the rider protection performances of various airbag jacket models, the Japan Automobile Research Institute (2011) has conducted an impact test and an inflation time test. Analysis of the measurements of shear and tension force in the neck have showed that the probability of a crash impact generating a serious injury to the neck is low if the rider wears an airbag jacket. The results of the chest impact test indicated that the probability of a crash impact generating an Abbreviated Injury Score of 3 (serious injury) to the chest region can be reduced by as much as 14% if the rider wears both a protector and an airbag jacket, as compared to wearing no protective gear . The time required to fully inflate an airbag jacket measured 90 ms for the fastest model and 180 ms for the slowest one.

There are a number of commercially available airbag jackets. However, there is no existing independent evaluation of their effectiveness. The European Technical Committee CEN/TC 162 "Protective clothing including hand and arm protection and lifejackets" has been working on a European

Standard which covers requirements and test methods for mechanically activated inflatable protectors for motorcycle riders. As of January 2014, this standard was not yet published.

High visibility clothing

As mentioned in Chapter 4, conspicuity is a crucial issue in the crash production and high visibility clothing has the potential – in addition to the PTW equipment (projectors, indicators) – to mitigate the problem of perception met by other road users as regards to PTWs. There are many types of motorcycle clothing available aimed to improve conspicuity. Some motorcycle protective clothing incorporates fluorescent and/or reflective sections. There are also many variants of a separate vest that can be worn over standard clothing. In addition there are fluorescent or reflective helmets, top panniers, backpacks, gloves etc. available. In general, all high visible clothing can be separated in two categories:

- fluorescent or bright clothing, vest, helmet, etc. to improve conspicuity during daytime;
- reflective parts incorporated in the jacket or vest to improve conspicuity during night time.

More recent developments in high visibility clothing are LED lighting in jackets or on backpacks. Still under development is a "glow in the dark" helmet, which charges light during daytime and then lights up when it is dark.

There are several studies on high visibility clothing of motorcyclists. However, the literature shows different results, depending on time and location, concerning their effects on safety.

Wells et al. (2004), conducted a large-scale case-control study on the effect of conspicuity on crash risk for New Zealand motorcycle riders. Fluorescent or reflective clothing, wearing a white or light helmet were associated with a reduced risk of motorcycle crashes. Olson et al. (1981) conducted a gap-acceptance experiment in which they varied, among others, the clothing of the motorcyclists. They found that during daytime car drivers accept smaller gaps when the motorcyclist is not wearing fluorescent clothing. While driving in the dark, the same applied to reflective clothing. Acceptance of a small gap was interpreted as the driver being unaware of a dangerous situation.

In contrast, studies based on reaction time or detection rate measures do not show a general trend towards a better or quicker detection of motorcyclists when the motorcyclist was wearing bright clothing. These studies concluded that it is the contrast with the environment that is important (Hole et al., 1996; Rogé et al., 2010; Gershon et al., 2012). For instance, Hole and colleagues found that in urban environments observers responded quicker to motorcyclists with bright coloured or fluorescent clothing than to motorcyclists with dark clothing. This effect was reversed in rural settings, the observers responded quicker to motorcyclists wearing dark clothing. They concluded that this was due to the brightness of the environment: the environment in the rural setting was clear blue sky. As summarised by de Craen et al. (2011), the most important aspect of PTW conspicuity is contrast with the environment.

Some conspicuity-related crashes can be prevented with high visibility clothing, but certainly not all. Schematically, when riding through highly dense traffic, a rider should wear bright clothing. When riding mostly in open-space (cruising) a rider is better off wearing darker clothing. At night, reflective clothing could be more effective. This implies that it is not always that simple to let motorcycles 'stand out' more in traffic, and makes it difficult to give a single message to motorcyclists that applies in all traffic situations.

Neck braces

Neck braces are designed to bring the head to a gentle stop in the event of a crash which will minimise the possibilities of the injuries caused by extreme (forward/ rearward/ sideways) movements of the head. Neck braces are most commonly used by off-road motorcycle riders.

As of today, for road riders, neck braces may have more drawbacks than benefits, as the reduction in head mobility (in particular the ability to look over the shoulder and clear blind spots) creates a greater risk of crash, than the possible benefit the product could bring in the unlikely risk of a neck fracture.

Conclusions

The use of helmets with adequate safety standards should be promoted and regulated. The helmet is the most important source of protection against severe injuries and death for both motorcyclists and moped riders. A helmet reduces dramatically the risk of being killed or severely injured. Helmet can prevent damages to the brain, which may entail very severe physical and psychological handicaps.

All countries should have and enforce a helmet law. A 100% wearing rate is the only acceptable objective. Still, not all OECD countries have a national helmet law. Enforcement should not only focus on wearing but also on *proper* wearing of a helmet (i.e. with fastened chin strap).

Airbag jackets appear to be a promising technology to minimise injury to the rider in case of a crash. Further research is needed to evaluate their effectiveness.

Research shows different results regarding the effectiveness of high visibility clothing in reducing conspicuity related crashes, depending on time and location, concerning their effects on safety. In short, when riding through highly dense traffic, a rider should wear bright clothing. When riding mostly in open-space (cruising) a rider is better off wearing darker clothing. At night reflective clothing could be more effective.

While research into the benefits of protective clothing is unequivocal, there are some issues with mandatory requirements for protective clothing. Clearly there are benefits from the introduction of harmonised standards to support the global product production and distribution. On the other hand, there is a trade-off, if a minimum standard is imposed that results in a price on equipment that exceeds the rider's willingness, or ability, to pay. While the introduction of mandatory requirements imposes a cost on riders, and may therefore be subject to significant community opposition, any increase in the use of protective clothing through promotion to increase rider awareness has the potential to provide significant benefits.

Further research and development into clothing and equipment with lower weight and improved ventilation should be encouraged. Promotion of the benefits of protective clothing and consequently consumer awareness is likely to be one of the key levers of this.

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