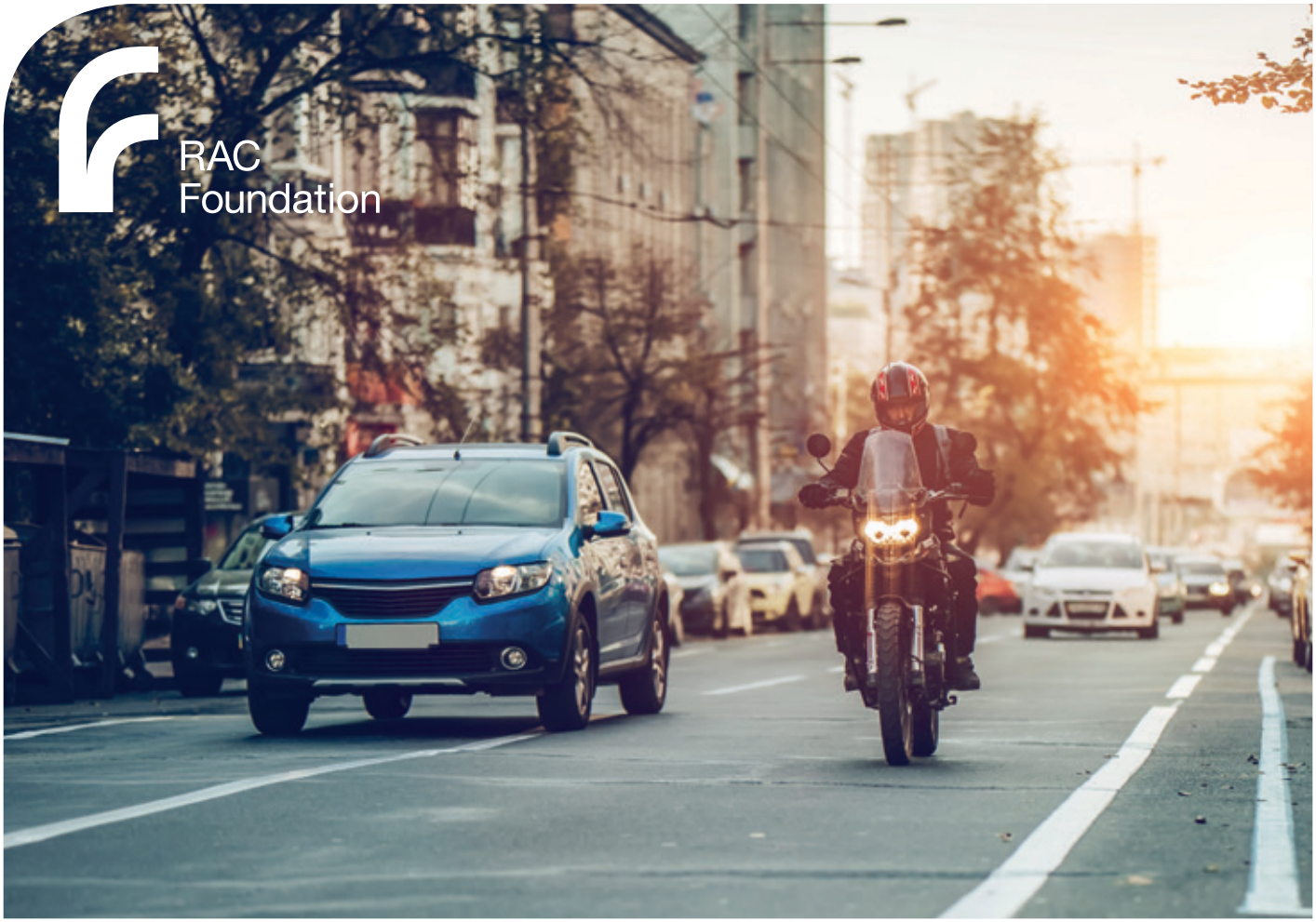
RAC Foundation



Stars or Standards?

A review of motorcycle protective clothing from the southern hemisphere

Liz de Rome PhD, Senior Research Fellow
Institute for Frontier Materials, Deakin University, Australia

Foreword

What we wear to ride a motorcycle or scooter really matters.

Our gear not only shields us from the wind and weather, it can save us from serious injury.

Which is why some riders choose to wear racing style tailored leather suits, complete with knee sliders, body armour and aerodynamic features.

But most of us, most of the time, aren't in the business of getting decked out in full race gear for a trip to the shops.

So, what should we wear? Not wearing protective gear is a sure way to end up with painful gravel-rash – at best – if you take a tumble. And the very term 'gravel-rash' rather underplays the seriousness of the injury, even a low-speed fall can involve.

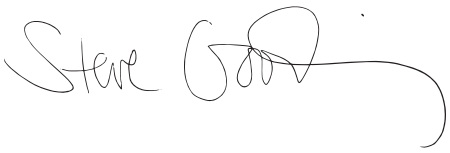
There is plenty of advice to be found in general terms, but when it comes to the performance of individual products the picture is less clear. Are those £150 gloves really safer than a £50 pair, or are you just paying for a product that has the look of racing kit but not the performance?

Hence, we were very interested to hear of the initiative in Australia to develop a star-rating system for protective clothing for motorcyclists. Therefore, we have commissioned this short report from Dr Liz de Rome, who sets out some of the issues about the choice between absolute standards and relative ratings that have been weighed down-under.

It will be interesting to see how Australia's biking consumers react to this still relatively new initiative.

In the meantime, remember that the best safety kit is only going to work to best effect if you choose the right fit and remember to wear it.

Steve Gooding



Director, RAC Foundation

Introduction

Motorcyclists represent an increasing proportion of road crash casualties across the world as the motorcycle fleet grows (WHO, 2015). Helmets are a proven safety measure, credited with reducing rider fatalities by 40% and head injuries by 60% (Liu et al., 2008). However, the majority of casualties do not die, and in countries with high helmet usage, for every rider fatality almost 60 are injured including 15 who are hospitalised (de Rome et al., 2011a; Department for Transport, 2017; Transport for NSW, 2018).

In Australia, with almost universal helmet usage, head injuries comprise just 8% of hospitalised riders, only half of whom have life-threatening injuries (Transport for NSW, 2018). The majority of casualties have non-fatal injuries, some of which will cause long-term physical impairment but may have been prevented or reduced by effective protective clothing (Schuller et al., 1986, Mayou et al., 2003, de Rome et al., 2012b). There have been few attempts to establish the benefits of protective clothing (other than helmets) for motorcyclists due to a prevailing view that it could have little effect on reducing fatal and serious injuries (ACEM, 2004). As a result, there has been little investment in monitoring the effectiveness of motorcycle clothing, specifically protective jackets, pants, gloves and boots.

Motorcycle clothing is an international industry largely dominated by Europe but with the major brands available across national borders. This paper outlines the research that has led to the development of a rating scheme for motorcycle protective clothing available in Australia and New Zealand.

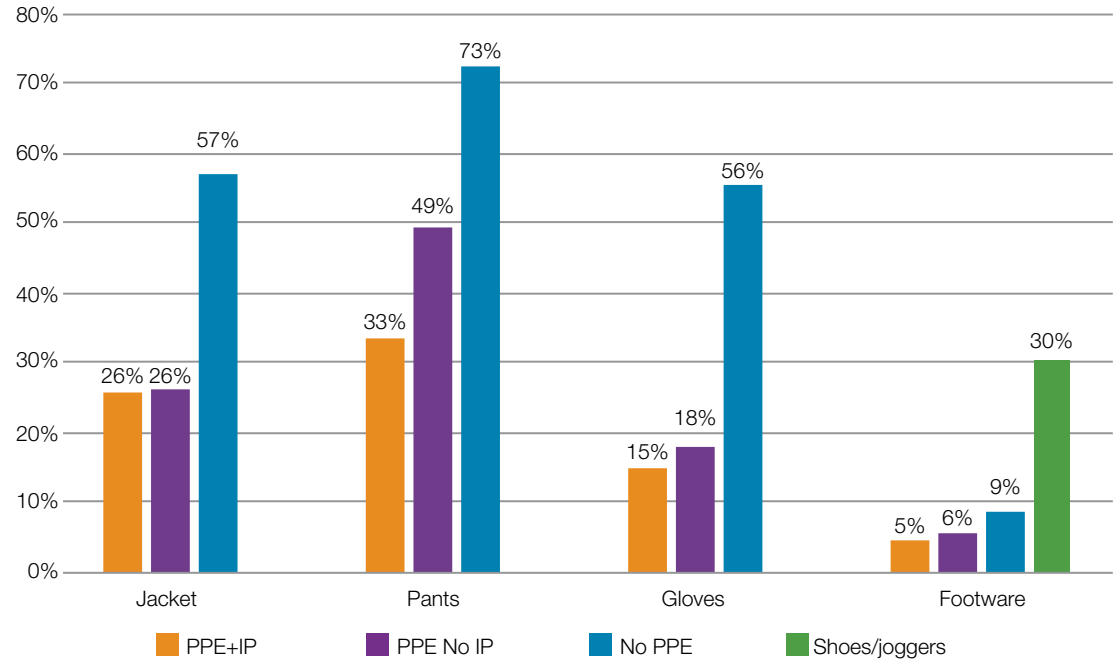
The benefits of personal protective equipment

In order to establish whether motorcycle personal protective clothing (PPE)[1] should be considered an effective safety measure, an in-depth motorcycle crash cohort study was conducted over 12 months in the Australian Capital Territory (de Rome et al., 2011a). Clothing worn by injured and uninjured riders was classified by type (jackets, pants etc), whether or not designed to provide injury protection (PPE or Non-PPE) and whether or not fitted with impact protection (PPE+IP) or (PPE No IP).

The most common injuries recorded included open wounds such as cuts, lacerations and abrasions, which are the injuries most likely to be reduced by protective clothing. Figure 1 shows the proportions of riders with open wound injuries by the levels of protection worn on each part of their bodies. For example, only 26% of those riders who were wearing a motorcycle jacket sustained any open wound injuries to their upper body, compared to 57% of those not wearing a motorcycle jacket. Such injury reductions are consistent with long-standing evidence from other motorcycle crash research (Aldman et al., 1981; Hurt et al., 1981; Schuller et al., 1986; Otte et al., 1987).

1 For the purpose of this article the term PPE (Personal Protective Equipment) will be used to refer to motorcycle protective clothing including jackets, pants or suits, gloves and boots but excluding helmets.

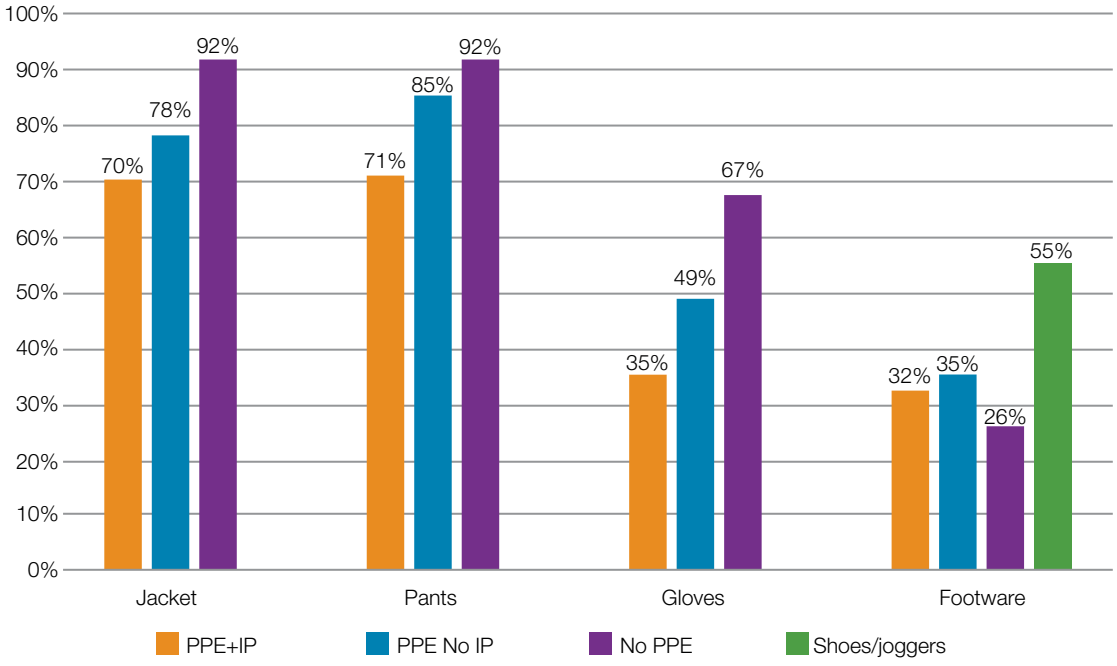
Figure 1. Proportion of riders with open wounds (cuts, lacerations or abrasions) for each level of protection



Note: MC=Motorcycle personal protective clothing; IP=Impact Protection
Source: de Rome et al. (2011a)

While there are obvious limits to the extent to which any clothing can prevent injuries, there was strong evidence that riders wearing PPE fitted with impact protection were less likely to sustain any injuries compared to those without impact protection or wearing non-motorcycle clothing. Figure 2 shows the proportions of crashed riders with any injuries by the level of protection to each area of the body.

Figure 2. Proportion of riders with any injuries for each level of protection



Note: MC=Motorcycle personal protective clothing; IP=Impact Protection
Source: de Rome et al. (2011a)

Given the wide range of impact types and forces in a motorcycle crash, a multivariate analysis was conducted to determine the relative risk for protected compared to unprotected riders when taking other factors associated with injury risk into account. Those factors included age, gender, motorcycle type, crash type (single or multivehicle), impact type (road surface slide, fixed object, other vehicle) and impact speed. The results provided strong evidence that riders wearing protective clothing were less likely to be hospitalised or to have any injuries, and were able to return to pre-crash work sooner than unprotected riders (de Rome et al., 2011a; de Rome et al., 2012b). The benefits were greater for those whose garments were fitted with impact protection (PPE+IP).

Table 1 shows the relative risk of injury for a protected rider compared to an unprotected rider according to the type of clothing, level of protection and body area. For example, the risk of any upper body injuries for riders wearing a motorcycle jacket fitted with impact protectors (PPE+IP) was 77%, (RR=0.77, 95% CI:0.68–0.86), which is 23% less than unprotected riders under the same crash conditions. Similar reductions were found for each area of the body protected with PPE+IP: 55% for hands/wrists, 61% for legs and 55% for feet. While there was no significant difference in the risk of any injuries at all between PPE without impact protection and non-motorcycle jackets, there were substantial reductions in the risk of open wounds (cuts, lacerations and abrasions). For example, compared to unprotected riders, the risk of open wounds was 37% for those with jackets fitted with IP (RR=0.37, 95%CI: 0.25-0.55) and a little higher, 42% for those without IP (RR=0.42, 95%CI: 0.17-1.01).

Table 1. Relative risk of any injury and open wound injuries by level of protection worn

Type of clothing	Any injury			Open wounds		
	Adj. RR*	95% CI	P-value	Adj. RR*	95% CI	P-value
Upper body						
No motorcycle jacket	Reference					
Motorcycle jacket (No IP)	0.83	0.65–1.05	NS	0.42	0.17-1.01	≤0.05
Motorcycle jacket (+IP)	0.77	0.68–0.86	≤0.0001	0.37	0.25-0.55	≤0.0001
Hand/wrist injuries						
No motorcycle gloves	Reference					
Motorcycle gloves (No IP)	0.69	0.46–1.04	NS	0.30	0.15-0.59	≤0.001
Motorcycle gloves (+ IP)	0.55	0.37–0.81	≤0.01	0.27	0.15-0.49	≤0.0001
Leg injuries only						
No motorcycle pants	Reference					
Motorcycle pants (No IP)	0.89	0.75–1.06	NS	0.63	0.42-0.95	≤0.05
Motorcycle pants (+ IP)	0.61	0.41–0.91	≤0.01	0.09	0.01-0.60	≤0.01
Feet/ankles						
Shoes/joggers	Reference					
Non-motorcycle boots	0.47	0.28–0.77	≤0.01	0.24	0.10-0.58	≤0.01
Motorcycle boots (No IP)	0.56	0.27–1.17	NS	0.17	0.02-1.47	NS
Motorcycle boots (+ IP)	0.55	0.35–0.85	≤0.01	0.10	0.03-0.34	≤0.001

*Adjusted for age, gender, motorcycle type, crash type (single or multivehicle), impact type (slide, object, other road user) and impact speed.
Note: IP=Impact Protection; RR=Risk Ratio; CI=Confidence Interval; P-value=Probability value
Source: de Rome et al. (2011a)

Despite the encouraging results of this study, the findings also revealed substantial levels of garment failure, with up to 30% of PPE products becoming holed, mostly due to abrasion damage, potentially exposing the wearer to injury (de Rome et al., 2011a).

Assessing protective performance

In 1993, the European Experimental Vehicles Committee commissioned a report which defined the limits of expectations for motorcycle protective clothing. It was determined that no clothing could be expected to protect a body from high-energy impacts, severe crushing or torsional forces, nor from massive penetrating injuries. It was concluded that clothing should be able to prevent most laceration and abrasion injuries, including muscle stripping and degloving injuries. It should also be able to reduce the severity of contusions, joint damage and fractures, and the contamination of open fractures (EEVC, 1993).

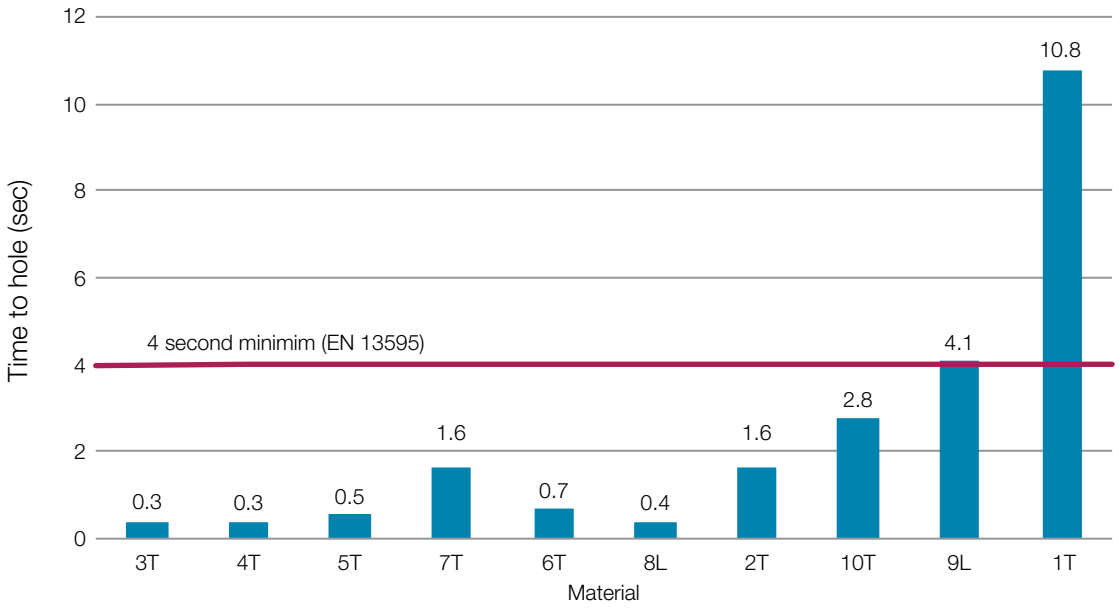
Due to the lack of monitoring, little is known about the effectiveness of those PPE products currently available. In evaluating the protective performance of garments, it is not simply a matter of observing crash-damaged clothing; it is necessary to determine the acceptable level of damage before the garment is deemed to have failed. The challenge is to determine whether:

1. Crash forces exceeded reasonable expectations of materials' performance.
2. The damage was sacrificial in the attempt to protect the wearer, or
3. The garment failed to provide the level of protection that should be expected.

The estimated impact speed in 75% of crashes in the de Rome 2011 study was 60 km/h or lower**,** which as an urban speed suggests the abrasion resistance of those garments was less than should be expected (de Rome et al., 2011a).

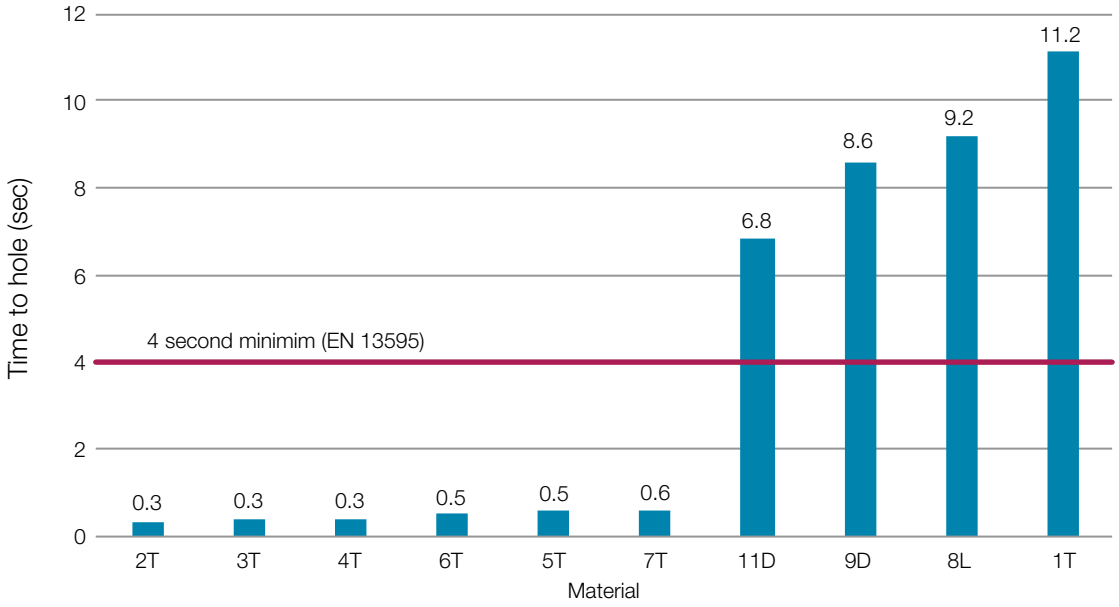
A follow**-**up study tested a selection of new all-season jackets and pants from a range of popular brands for abrasion resistance as specified by EN 13595 (CEN, 2002a). Only two of ten jackets and four of eleven pants lasted the minimum four or more seconds required to pass the EU Standard. Figures 3 and 4 show the results of impact abrasion resistance in time to hole (seconds) from point of impact (de Rome et al., 2015b). Such poor performance for impact abrasion resistance is of great concern, given EN 13595 has been the standard for motorcycle jackets and pants in Europe since 2002 (CEN, 2002a). It is part of a suite of EU Standards for motorcycle PPE, which are the only regulatory standards for on-road motorcyclists' protective clothing worldwide.

Figure 3. Motorcycle jackets impact abrasion resistance – time to hole in seconds by primary material



Note: L=Leather; T=Textile
Source: de Rome et al. (2015b)

Figure 4. Motorcycle pants impact abrasion resistance – time to hole in seconds by primary material



Note: L=Leather; T=Textile; D=Denim (reinforced)
Source: de Rome et al. (2015b)

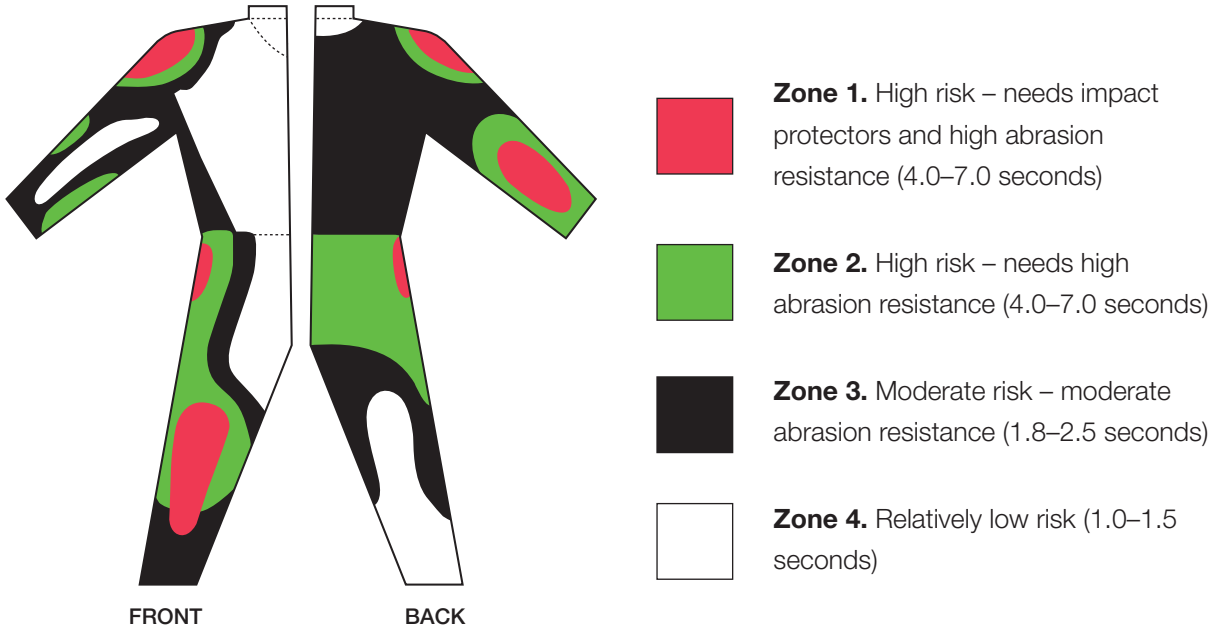
These results raised the question as to whether the Standard's requirements were too rigorous. Meredith attempted to reproduce the damage to garments worn by hospitalised riders to estimate the probability of injury associated with the duration of abrasion resistance (Meredith et al., 2017). Her results confirmed the validity of the abrasion resistance requirements of EN 13595, indicating that an abrasion time of 4 seconds equates to a 37% probability of soft tissue injury, compared to 53% with a 1-second abrasion resistance.

The European standards

The European Standards for motorcycle protective clothing were developed by the European Committee for Standardization (CEN) to enable manufacturers to meet their statutory obligations for all personal protective equipment (PPE) to comply with a relevant standard (CEC, 1989).

Britain led the way with the research and development of standards for motorcycle protective clothing at Cambridge University (Woods, 1999). The current European Standards are largely based on the Cambridge Standard, which identified four levels and areas (zones) of crash impact risk and the relevant mechanisms of protection from the analysis of crash damage and injury data (Woods, 1996a). Figure 5 illustrates the motorcycle crash impact risk zones.

Figure 5. Motorcycle crash impact risk zones



Source: adapted from Woods (1996a)

The principal mechanisms of protection for jackets, pants and gloves identified by Woods include:

1. outer materials that are resistant to abrasion, cuts, tears and bursts;
2. seams and fastenings that are burst-resistant and will prevent the garment and impact protectors from moving out of place in a crash;
3. linings made of slippery material to prevent skin shear injuries; and
4. shields fitted over the most exposed parts of the body (e.g. shoulders, elbows, knees etc.) to attenuate the force of direct impacts (after Woods, 1996a).

The key standards for motorcycle PPE include jackets, pants and one-piece suits (EN 13595 1-4), gloves (EN 13594), impact protectors (EN 1621-1) and back protectors (EN 1621-2) (CEN, 1998; CEN, 2002a; CEN, 2002b; CEN, 2003).

While enforceable only in Europe, the EU Standards have provided a unique reference and benchmarks for research and development globally. The result has been the emergence of new technologies and a new generation of protective clothing products for motorcyclists in the international market. Perhaps the most significant changes have been the widespread usage of impact protectors and the development of denim jeans reinforced with high-abrasion-resistant lining, which are providing better abrasion resistance than many of the more traditional textiles. However, from their inception, the Standards were not universally supported by riders, industry or governments.

Riders' concerns

Rider groups were concerned that mandatory standards for manufacturers might extend to mandatory usage by riders. Despite the consumer benefits in assuring product protective performance, many riders were more concerned about being forced to wear garments that were not comfortable or functional for their riding purposes (de Rome et al., 2012a).

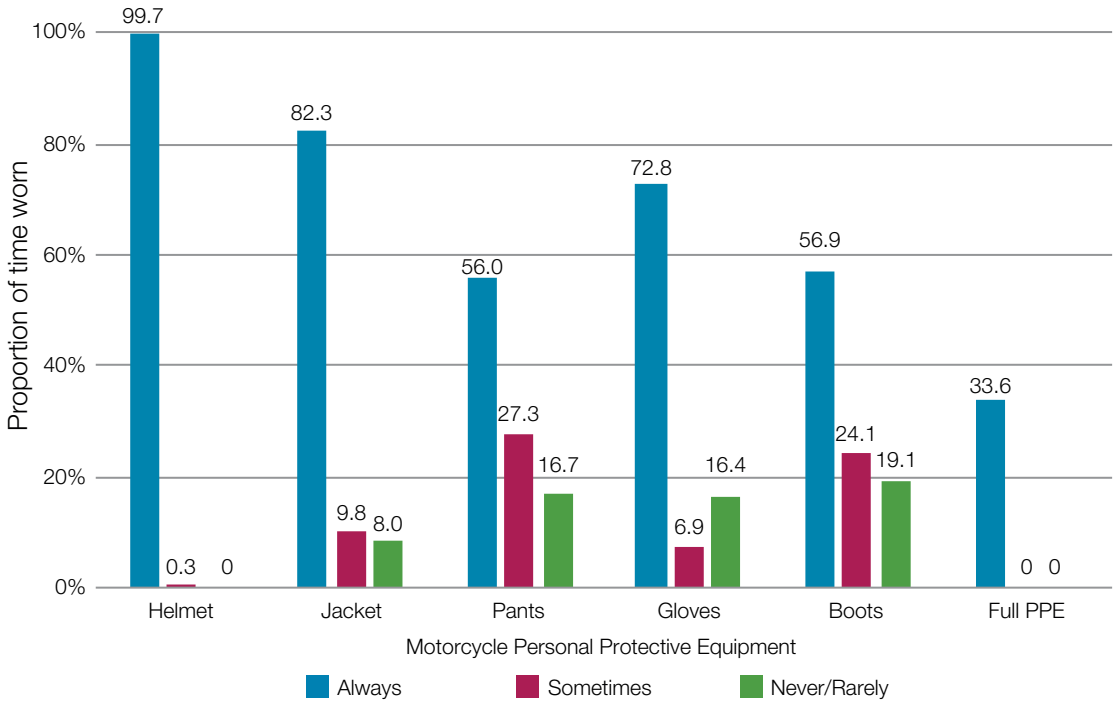
Such concerns are not without reasonable grounds, because protective materials tend to be heavy, inflexible and insulating. Such materials can create a physiological burden, potentially impairing the wearer's task performance and increasing their risk of errors (McLellan et al., 2012). In most industrial contexts, protective clothing is worn only for the duration of exposure to a hazard, such as fire-fighting, where the risk is integral to the role. This is not the case with motorcycling, which is primarily a form of transport when injury protection is required only in exceptional circumstances.

Many motorcyclists vary the level of protection worn according to riding conditions and purpose. Riders are more likely to wear full PPE on recreational rides and less likely when commuting, due to the dilemma of dressing for either the ride or their destination (Wishart et al., 2009). In addition, those who do not 'always' wear PPE are three times less likely to wear it in hot conditions (Koch et al., 1998; de Rome et al., 2011b).

Concerns about the potential safety risk for riders wearing protective clothing in hot conditions were first raised in a review of motorcycle safety (EEVC, 1993). It is only recently that the physiological impact on riders of wearing PPE in hot weather and the potential risks of cognitive and psychophysical impairment has been associated with thermally inefficient motorcycle PPE (de Rome et al., 2015a; de Rome et al., 2016a).

Figure 6 shows the proportion of motorcyclists who report that they always, sometimes or never/rarely wear each type of protective clothing in a population-based study in the State of NSW, Australia (de Rome et al., 2016b).

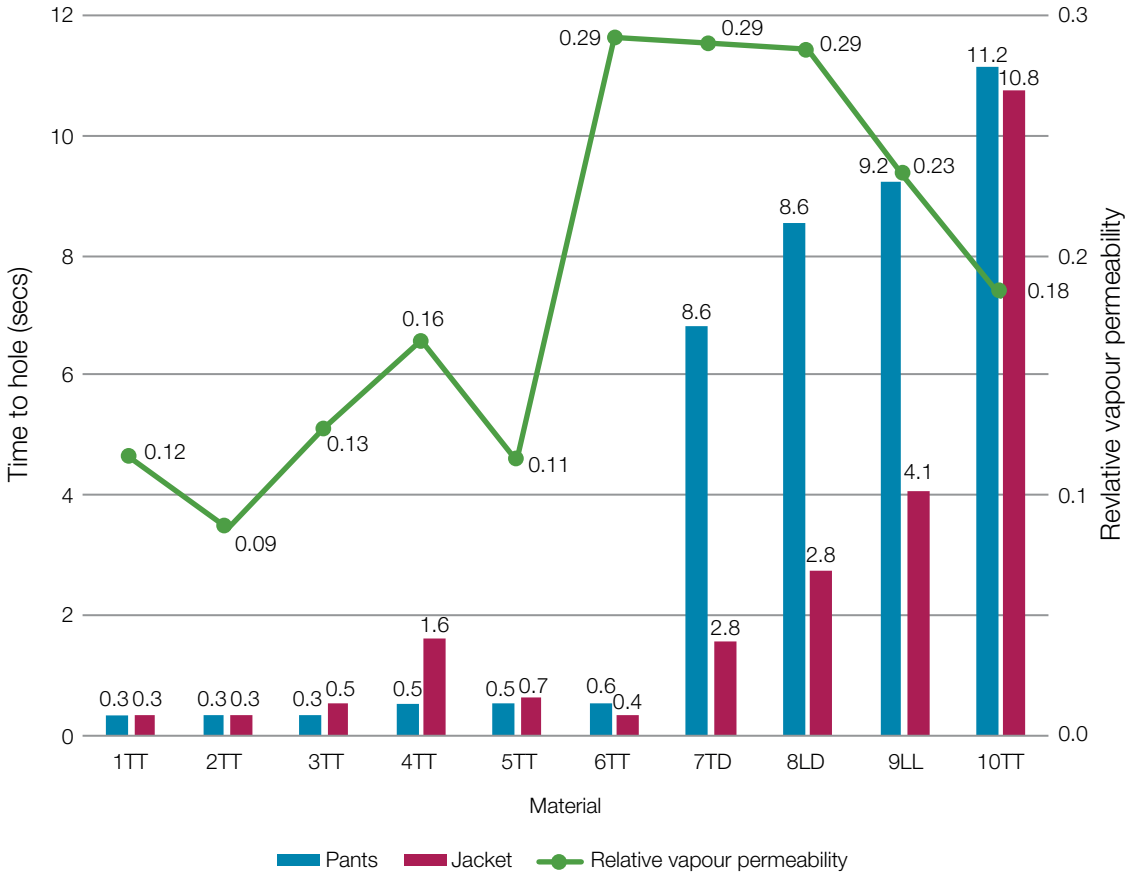
Figure 6. Usage of motorcycle PPE in NSW, Australia



Source: de Rome et al. (2016b)

The thermal efficiency of a garment relates to its ability to allow the body to regulate core temperature through a balance of heat insulation and sweat evaporation. Thermal efficiency is assessed by measuring the dry heat and moisture vapour resistance of a garment, from which its relative vapour permeability can be calculated. The Vapour Permeability Index is a scale from 0 to 1, where the higher the score the better the heat insulation relative to breathability. Ten motorcycle protective suits, including textile, leather and reinforced denim products, were tested for thermal efficiency and abrasion resistance. All garments demonstrated poor thermal management (<0.29 vapour permeability), meaning they were very likely to be uncomfortable in hot conditions. No association was found between thermal efficiency and protection in terms of abrasion resistance for the suits tested (de Rome et al., 2015b). Figure 7 shows the vapour permeability and abrasion resistance of motorcycle jackets and pants of different materials.

Figure 7. Abrasion resistance (s) and vapour permeability of ten all-season motorcycle protective garments in NSW, Australia



Note: T=Textile; D=Denim (reinforced); L=Leather (for example TD=Textile Jacket/Denim Pants)
Source: de Rome et al. (2015b)

The challenge for industry

In the absence of rider support or government enforcement of the European Standards since 2002, industry compliance has been limited. Whereas some manufacturers, particularly in Britain, adopted the EU Standards as their benchmark, others considered the requirements of EN 13595 to be too rigorous for non-professional riders. Manufacturers continued to produce motorcycle garments, but circumvented the need for testing and certification under the Standards by avoiding any reference to 'protection' or 'safety' in marketing their products (de Rome et al., 2012a).

It is a considerable challenge for manufacturers to devise garments that can provide protection from injury and the elements without restricting the riders' ease of movement or creating discomfort or fatigue. Effective motorcycle clothing should also enhance rider safety by increasing conspicuity and maintaining riders' physiological and psychological condition by keeping them dry, warm, comfortable and alert (EEVC, 1993).

For almost 20 years since the development of the Standards, there has been an impasse, with widespread lack of industry compliance, eventually leading to some individual EU member states developing their own alternative test specifications. The best known of these is the French Protocol,

issued by the French Standards Association. It is a modified version of EN 13595, with lower test performance requirements and designated as being for 'non-professional' riders. In response, CEN conducted a review of EN 13595, and an alternative new standard for motorcycle jacket, pants and suits (Pr EN 17092) has been developed, also designated for non-professional riders and with substantially reduced protective performance requirements compared to EN 13595.

The proposal to replace EN 13595 with Pr EN 17092, proved controversial amongst EU member states resulting in a resolution that the two standards should exist in parallel until at least 2023, when they will be reviewed and potentially merged. It is essential that this time be used for the reduced test performance requirements of Pr 17092 to be validated against real world crash outcomes. EN 13595 is based on evidence from studies of motorcycle crash impacts and injuries (Prime et al., 1984; Woods, 1996a; Woods 1996b). It has also subsequently validated in real world crashes and laboratory tests (de Rome et al., 2014; Meredith et al., 2014; Meredith et al., 2017). There is currently no publicly available information as to the scientific basis for the performance requirements of Pr EN 17092.

Stars not standards in the Southern Hemisphere

Observation of the European experience and lobbying by the Australian Motorcycle Council has led Australia and New Zealand to establish a star rating scheme as an alternative to the standards approach. The rating scheme, called MotoCAP (Motorcycle Clothing Assessment Program) is the result of a review commissioned by the Motor Accidents Authority of NSW in 2011 to investigate options for increasing the availability of credible consumer information about motorcycle protective clothing (de Rome et al., 2012a). The review recommended the establishment of an independent scheme to purchase, test and publicise results on the protective performance and thermal management of motorcycle PPE.

Ratings were considered to be more appropriate than the pass/fail basis of a standards approach due to the multiple functions required of motorcycle clothing and the different dimensions of performance involved. In particular, the pass/fail basis of a standards approach implies that all certified garments will perform equally, providing little incentive for industry to exceed the minimum acceptable performance. In contrast, ratings schemes using the same test methods can allow products to be ranked and rated on their relative performance.

The availability of objective scientific information on the performance of competing products could be of advantage to the industry as well as their customers. Ratings provide the industry with the information, incentives and confidence to compete on product quality with transparent indices for performance. The ratings scheme is also expected to reduce the market for lower quality products (de Rome et al., 2012a).

MotoCAP is funded by stakeholder agencies including the road authorities, motor accident injury compensation schemes and motoring organisations from across Australia and New Zealand. Garments are randomly selected and purchased each year by secret buyers to represent 10% of the motorcycle protective jackets, pants and gloves for on-road riding available in the retail market in each country. Garments are tested and rated on two dimensions – injury protection and thermal management – using test methods from the relevant existing established industry standards. The MotoCAP website (www.motocap.com.au), with the first test results for leather jackets and denim riding pants, was officially launched in September 2018.

Conclusions

The Australian and New Zealand MotoCAP scheme is the outcome of many years of research and consultation with riders and industry. Crash studies have provided strong evidence that effective motorcycle clothing can prevent or reduce many of the injuries most commonly sustained by riders in motorcycle crashes. The objectives of the scheme are to reduce the prevalence of injuries by increasing the usage and effectiveness of the PPE available by enabling riders to make well-informed purchasing decisions, and encouraging industry to provide garments that are suitable for use in hot conditions. Consultations have indicated that engaging the market would be more productive and cost-effective than regulation for achieving these goals.

Although MotoCAP is designed for the Australian and New Zealand markets, motorcycle protective clothing is an international industry and the community of riders is equally international. It is anticipated that over time increasing numbers of riders from other countries will refer to the MotoCAP website when choosing their gear.

References

Association of European Motorcycle Manufacturers (ACEM), 2004. *MAIDS in-depth investigation of accidents involving powered two wheelers: Final report 1.2. Brussels.* Accessed 6 November 2018 from http://www.maids-study.eu/

Aldman, B., Cacciola, I., Gustafsson, H., Nygren, A., Wersall, J., 1981. The protective effect of different kinds of protective clothing worn by motorcyclists. In: Charpenne, J.P.C.A. ed. *Proceedings of the 6th International Conference of the Research Council on the Biomechanics of Impact*. IRCOBI, Salon-de-Provence (France), pp. 1–9.

CEC, 1989. *The Council of the European Communities directive on the approximation of the laws of the member states relating to personal protective equipment 89/686/eec*. Office for Official Publications of the European Communities, 1989L0686-08/10/1996 CONSLEG. Accessed 6 November -2018 from https://ec.europa.eu/growth/sectors/mechanical-engineering/personal-protective-equipment_en

CEN, 1998. Motorcyclists' protective clothing against mechanical impact: Requirements and test methods for impact protectors. EN 1621-1:1998. European Committee for Standardization, Brussels.

CEN, 2002a. Protective clothing for professional motorcycle riders: Jackets, trousers and one piece or divided suits – General requirements. EN 13595-1:2002. European Committee for Standardization, Brussels.

CEN, 2002b. Protective gloves for professional motorcycle riders: Requirements and test methods. EN 13594:2002. European Committee for Standardization, Brussels.

CEN, 2003. Motorcyclists' protective clothing against mechanical impact: Motorcyclists' back protectors – requirements and test methods. EN 1621-2:2003. European Committee for Standardization, Brussels.

de Rome, L., Brown, J., 2016a. Motorcycle protective clothing: The cognitive and psychophysical concomitants of thermal strain. Australasian Road Safety Conference. Australasian College of Road Safety, Canberra.

de Rome, L., Fitzharris, M., Baldock, M., Fernandes, R., Ma, A., Brown, J., 2016b. The prevalence of crash risk factors in a population-based study of motorcycle riders. *Injury* 47 (9), pp. 2025–2033.

de Rome, L., Gibson, T., Haworth, N., Ivers, R., Sakashita, C., Varnsverry, P., 2012a. *Improving consumer information about motorcycle protective clothing products* (2012). A report prepared for the Motor Accidents Authority of NSW (MAA), commissioned by the Australian & New Zealand Heads of Compulsory Third Party Insurance. The George Institute for Global Health, Sydney, pp. 131.

de Rome, L., Ivers, R., Fitzharris, M., Du, W., Richardson, D., Haworth, N., Heritier, S., 2011a. Motorcycle protective clothing: Protection from injury or just the weather? Accident Analysis and Prevention 43 (6), pp. 2035–2045.

de Rome, L., Ivers, R., Fitzharris, M., Haworth, N., Heritier, S., Richardson, D., 2012b. Effectiveness of motorcycle protective clothing: Riders' health outcomes in the six months following a crash. *Injury* 43, pp. 2035–2045.

de Rome, L., Ivers, R., Haworth, N., Heritier, S., Du, W., Fitzharris, M., 2011b. Novice riders and the predictors of riding without motorcycle protective clothing. Accident Analysis & Prevention 43 (3), pp. 1095–1103.

de Rome, L., Meredith, L., Ivers, R., Brown, J., 2014. Validation of the principles of injury risk zones for motorcycle protective clothing. Doi: 10.1016/j.Jsr. *Journal of Safety Research* 50, pp. 83–87.

de Rome, L., Taylor, E.A., Croft, R.J., Brown, J., Fitzharris, M., Taylor, N.a.S., 2015a. Thermal and cardiovascular strain imposed by motorcycle protective clothing under Australian summer conditions. *Ergonomics*, pp. 1–29.

de Rome, L., Taylor, N.a.S., Troynikov, O., Hurren, C., Fitzharris, M., Croft, R., Brown, J., 2015b. *Motorcycle protective clothing: Physiological and perceptual barriers to their summer use.* Australasian Road Safety Conference. Australasian College of Road Safety, Broadbeach, Queensland.

Department for Transport, 2017. Reported road casualties Great Britain, complete report: 2016: National statistics. Road accidents and safety statistics. Department for Transport, London.

EEVC, 1993. Report on motorcycle Safety. Report of the Ad-hoc Group on Motorcycle Safety, 1993. European Experimental Vehicles Committee, Brussels, pp. 75.

Hurt, H.H., Ouellet, J., Wagar, I., 1981. Effectiveness of motorcycle safety helmets and protective clothing. In: *Proceedings of the 25th Annual Meeting of the Association for the Advancement of Automotive Medicine*, San Francisco, pp. 223–235.

Koch, H., Brendicke, R., 1998. Protective clothing: Wearing patterns, knowledge and attitudes of motorcyclists. In: Rothengatter, T., De Bruin, R. eds. *Road user behaviour: Theory and research.* Van Gorcum & Company, Assen, Netherlands.

Liu, B., Ivers, R., Norton, R., Boufous, S., Blows, S., Lo, S., 2008. Helmets for preventing injury in motorcycle riders (review update). *Cockrane Database of Systematic Reviews* Issue 1, p. 37.

Mayou, R., Bryant, B., 2003. Consequences of road traffic accidents for different types of road user. *Injury* 34 (3), pp. 197–202.

McLellan, T.M., Daanen, H.a.M., 2012. *Heat strain in personal protective clothing: Challenges and intervention strategies*. Springer, pp. 99–118.

Meredith, L., Brown, J., Ivers, R., de Rome, L., 2014. Distribution and type of crash damage to motorcyclists' clothing: Validation of the zone approach in the European Standard for motorcycle protective clothing, EN-13595. *Traffic Injury Prevention* 15 (5), pp. 501-507.

Meredith, L., Hurren, C., Clarke, E., Fitzharris, M., Baldock, M., de Rome, L., Olivier, J., Brown, J., 2017. Validation of the abrasion resistance test protocols and performance criteria of en13595: The probability of soft tissue injury to motorcycle riders by abrasion resistance of their clothing. *Journal of Safety Research* 61, pp. 1–7.

Otte, D., Middelhauve, V., 1987. Quantification of protective effects of special synthetic protectors in clothing for motorcyclists. In: Cesari, D., Charpenne, A. eds. *Proceedings of the International Conference of the Research Council on the Biomechanics of Impact.* IRCOBI, Birmingham, UK, pp. 1–18.

Prime, D.M., Woods, R.I., 1984. Tests on the protection afforded by various fabrics and leathers in a simulated impact of a motorcyclist on a road surface. In: Cesari, D., Charpenne, A. eds. *Proceedings of the International Conference of the Research Council on the Biomechanics of Impact.* IRCOBI, Delft, pp. 253–264.

Schuller, E., Beir, G., Spann, W., 1986. Disability and impairment of protected and unprotected motorcycle riders. SAE International Congress and Exposition – Crash Injury Impairment and Disability: Long Term Effects, Detroit, MI. The Engineering Society for Advancing Mobility Land Sea Air and Space (SAE), Warrendale, PA 15096, pp. 51–56.

Transport for NSW, 2018. Interactive crash statistics. Accessed 30 November 2018 from http://roadsafety.transport.nsw.gov.au/statistics/interactivecrashstats/index.html

WHO, 2015. *Global status report on road safety*. Accessed 23 November 2018 from http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/

Wishart, D., Watson, B., Rowden, P., 2009. Motorcycle rider protective apparel wearing: Observational study results from the Brisbane and Canberra regions. *Journal of the Australasian College of Road Safety* 20 (4), 52–59.

Woods, R.I., 1996a. Specification of motorcyclists' protective clothing designed to reduce road surface impact injuries. In: Johnson, J.S., Mansdorf, S.Z. eds. *Performance of protective clothing.* American Society for Testing and Materials, ASTM STP 1237, Philadelphia, pp. 3–22.

Woods, R.I., 1996b. Testing of protective clothing for motorcyclists: Validation of laboratory tests by accident studies. In: Johnson, J.S., Mansdorf, S.Z. eds. *Performance of protective clothing.* American Society for Testing and Materials, Philadelphia, pp. 43–56.

Woods, R.I., 1999. *The Cambridge Standard for motorcyclists' clothing. Part 1. Jackets, trousers, one piece suits and two piece suits, designed to provide mechanical protection against some injuries.* Protective Clothing Research Facility, Physiological Laboratory, Cambridge University, Downing Street, Cambridge, UK.

About the Author

Dr Liz de Rome has worked in motorcycle safety research and strategic planning for almost 20 years. She developed the first Australian motorcycle safety strategic plan including a unique website to inform riders with evidence-based information for motorcycle safety. In 2011 Liz successfully challenged prevailing assumptions about the potential for motorcycle personal protective clothing (PPE) to reduce the risk and severity of injuries, but also found substantial proportions of PPE failed under crash conditions. Concern about low usage rates spurred her to investigate the potential risks of heat strain due to PPE unsuitable for hot conditions. Liz has been a long-time advocate for a star rating scheme for PPE and has led the development of the model for the Motorcycle Clothing Assessment Program – MotoCAP for Australia and New Zealand. Her other work includes The Good Gear Guide for Motorcycle & Scooter Riders and the development Victoria's new Motorcycle Graduated Licensing System (M-GLS).

Liz is Senior Research Fellow of Motorcycle Safety at Deakin University in the Institute for Frontier Materials. She is a member of the National and State Executives of the Australasian College of Road Safety and the US Transportation Research Board Standing Committee on Motorcycles and Mopeds.

Acknowledgements

The author would like to acknowledge the contributions of Chris Hurren, Tom Gibson and Paul Varnsverry to the research and development leading to the star rating scheme for motorcycle clothing. The project was an initiative of the Motorcycle Council of NSW and has the ongoing support of the Australian Motorcycle Council. The implementation of the scheme has been led by the NSW Centre for Road Safety and is funded and managed by a collaboration of government agencies, insurers and motoring organisations from across Australia and New Zealand. For further details see: www.motocap.com.au.

Disclaimer

RAC Foundation

The Royal Automobile Club Foundation for Motoring Ltd is a transport policy and research organisation which explores the economic, mobility, safety and environmental issues relating to roads and their users. The Foundation publishes independent and authoritative research with which it promotes informed debate and advocates policy in the interest of the responsible motorist.

RAC Foundation
89–91 Pall Mall
London
SW1Y 5HS

Tel no: 020 7747 3445
www.racfoundation.org

Registered Charity No. 1002705

Designed and printed by the Javelin Partnership Ltd. Tel: 0118 907 3494
Produced on paper from a managed sustainable source which is FSC certified as containing 50% recycled waste.