THE INJURY REDUCTION BENEFITS OF

MOTORCYCLE PROTECTIVE CLOTHING

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1. Abstract

An Australian survey of riders indicates that, while most riders fully protect their head and upper body, they are less likely to wear motorcycle pants or boots. This is despite long established patterns of injury risk confirming that the legs are the part of the body most likely to be injured in a motorcycle crash. Although protective clothing cannot prevent injuries in a high impact crash, most motorcycle crashes do not occur at high speed. There is now evidence that perhaps half of all motorcycle injuries are relatively minor soft tissue injuries, which could be reduced or prevented by the use of effective protective clothing. Well designed motorcycle clothing may also reduce the risk of crashes related to fatigue and distraction caused by heat, cold or wet stress and discomfort.

The essential features of effective protective clothing are well established and there are mandatory standards in Europe for any clothing purporting to provide injury protection. The standards provide manufacturers with a single bench mark and objective tests that can verify the protective performance of their products. The need for such standards is demonstrated by independent consumer evaluations applying the standards tests, which have revealed serious levels of failure in many of the products available in the European market.

If the use of protective clothing is to be encouraged, road safety authorities and the motorcycle accessories industry need to devise a means of assuring riders that products will provide the expected benefits. The motorcycle industry operates in an international market and the adoption of the European Standards as international standards could provide an effective means to ensure such products are fit for the intended purpose.

2. Introduction

For the purpose of this discussion protective clothing for motorcyclists is taken to include gloves, boots, a long sleeved jacket and pants, or one piece suit, made of leather or other fabric with high abrasion and tear resistance. Most items, these days will also include some impact protectors to absorb or distribute force at specific impact points. Our discussion does not include helmets because they are mandatory in Australia and usage is very widely accepted.

Motorcyclist clothing is required to serve a number of different purposes, these include to:

1. Prevent or minimise injury in the case of a crash,
2. Protect from the elements – wind, rain, cold and heat,
3. Draw the attention of other motorists (conspicuity),
4. Make a desired fashion statement/ be appropriate for general wear.

Our focus is on protection from injury in a crash, although comfort and conspicuity are also safety issues for motorcyclists.

Comfort in terms of protection from the elements is important in reducing fatigue,

distraction and dehydration and in this sense it may prevent crashes. The challenge for manufacturers is to provide protection from injury, as well as from the elements without restricting ease of movement or creating heat discomfort and fatigue.

The potential for clothing to increase a riders' visibility to other motorists as a crash reduction strategy is less well established. However it is an issue that every rider needs to consider as failure to see the motorcyclist is a factor for up to half of the drivers who collide with motorcycles (EEVC, 1993).

The issue of fashion is not entirely trivial. One of the objectives of this project is to try to help riders distinguish between clothing features that are pure fashion and those that have some genuine protective merit. Motorcycle clothing is more functional if it is also comfortable and suitable for wear once the rider has reached their destination.

3. The injury reduction benefits of motorcycle clothing in a crash

The injury reduction potential of motorcycle protective clothing has been well established for at least 30 years (Feldkamp, et al 1976; Zettas et al, 1979; Hurt, Ouellet & Wager, 1981; Schuller et al., 1982 & 1986; Otte & Middelhauve, 1987; Hell & Lob, 1993; Otte et al 2002; ACEM, 2004).

Over 20 years ago, Schuller reported that injured riders, who had been wearing leathers, spent on average 7 days less in hospital, and returned to work 20 days earlier than unprotected riders. The protected riders were 40% less likely to have suffered permanent physical defect. It was concluded that protective clothing can prevent or reduce 43% of injuries to soft tissue and 63% of deep and extensive injuries (Schuller et al, 1986). More recently, Otte found that impact protectors reduced the incidence of complex leg fractures and reported significant injury reduction for riders wearing high boots (Otte et al, 2002).

Most research has described the injury reduction benefits of protective clothing in relation to soft tissue injuries. Protective clothing has also been found to prevent or reduce injuries such as cuts and abrasions, exhaust pipe burns, friction burns and the stripping away of skin and muscle. Protective clothing may also reduce the risk of infection from wound contamination and consequent complications in the healing of severe injuries. (e.g. Schuller et al, 1986, Pegg & Mayze, (1983) Otte & Middelhauve, 1987; Hell & Lob, 1993).

There are, of course, limits to the extent that clothing can prevent injury, particularly in high impact crashes, however there is also evidence that most motorcycle crashes are not high impact. The European Experimental Vehicles Committee's review of research into motorcycle accidents, found that the majority of motorcycle collisions take place at fairly low speeds, the average impact being at between 30 and 45 kilometers per hour (EEVC, 1993). According to the recent MAIDS (Motorcycle Accident In depth Study), 75% of all motorcycle crashes occur at speeds of 50 km/h (35 mph) or less (ACEM, 2004).

Crashes where the rider slides along the road surface without impacting a fixed object are less likely to result in severe injuries and are the types of crashes where protective clothing can offer the greatest injury reduction (Hell & Lob, 1993, Otte et al, 1987).

MAIDS reported that some 40% of riders tumbled, rolled or slid along the road from the point of the crash without any further impact with another object (ACEM, 2004).

The prevention or reduction of minor soft tissue injuries is not a trivial benefit. Overall,

almost half (49%) of all the injuries recorded in MAIDS were rated to be minor or Level 1 on the Abbreviated Injury Scale (AIS 1)[1].

Table 1 shows the severity of the most serious injury suffered by each of the riders in the MAIDS study. The most serious injury suffered by 39% of riders was rated as minor or AIS Level 1. These are the injuries that protective clothing may have prevented or reduced.

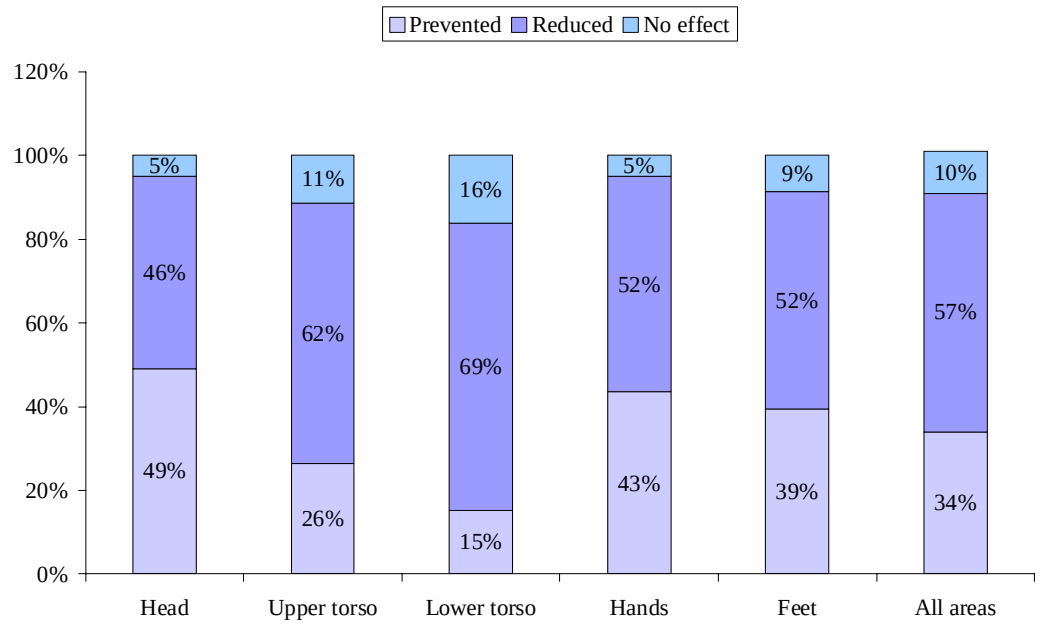
Table 1 Maximum injury severity per rider, (MAIDS, 2004)

Severity AIS Level	No injury 0	Minor 1	Moderate	Serious 3	Severe 4	Critical 5	Not Survivable 6
Proportion of riders	2%	39%	33%	16%	4%	5%	2%

The figures in Table 1 include all riders, many of whom were wearing protective clothing. The MAIDS investigators tried to establish whether clothing had reduced or prevented the incidence of AIS Level 1, minor injuries such as cuts, gravel rash, friction burns etc.

Figure 1 illustrates the proportion of riders considered to have been protected from minor injury by their clothing. The graph includes only those riders who were wearing protective clothing and sustained a direct impact that could have caused an injury to that part of the body. For example, the column for the lower torso indicates that clothing prevented minor soft tissue injury for 15% and reduced such injuries for over two thirds (69%) of these riders. Only 16% sustained minor soft tissue injuries to the legs and lower torso despite their clothing. This does not preclude those riders from also suffering some more severe injury such as a fracture, but it does mean they were less likely to have complications such as blood loss or infection from open wounds.

Figure 1. Riders protected from minor injury by clothing.

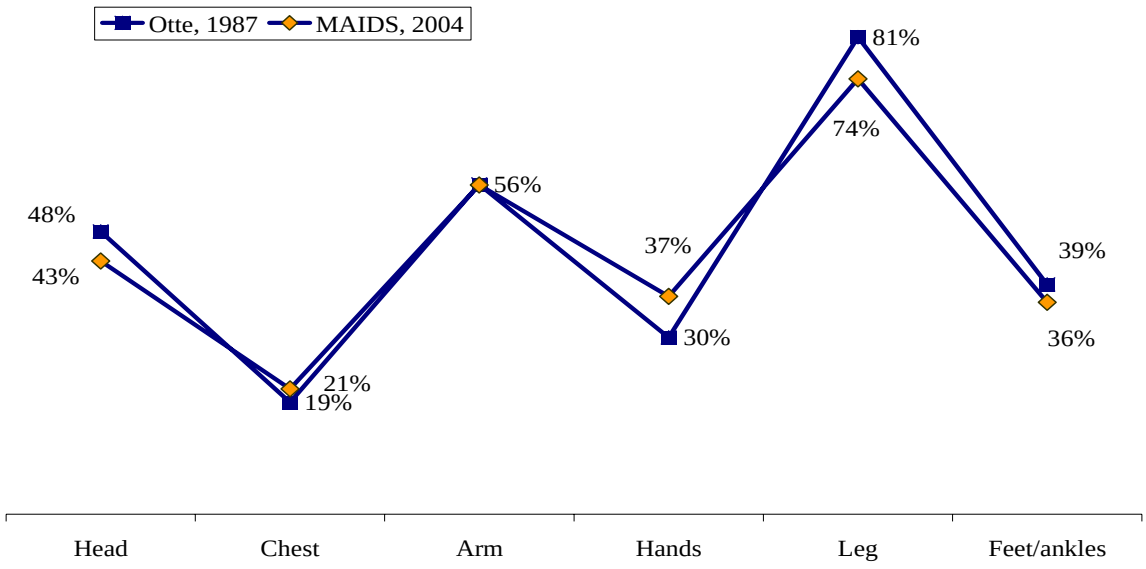


[1] On the Abbreviated Injury Scale (AIS) a 0 indicates Un-injured and 6 is Not survivable.

The parts of the body that are most frequently injured in crashes are a well established pattern. In 1993, the European Experimental Vehicles Committee (EEVC) recognized that, while head injuries account for 80% of fatalities, the legs are the area most frequently injured in a motorcycle crash (EEVC, 1993). Similar patterns of injury by body part have been documented by a range of crash studies studies in USA, UK and Germany (Hurt et al, 1981; Craig et al, 1983; Schuller et al, 1986; Otte & Middelhauve, 1987).

Figure 2 illustrates the distribution of rider injuries in 1987 (Otte & Middelhauve, 1987) compared to the recent MAID Study (ACEM, 2004). It reveals a remarkably consistent pattern despite changes in vehicle and equipment safety in the intervening decades.

Figure 2. Motorcycle injury patterns 1987 vs 2004.

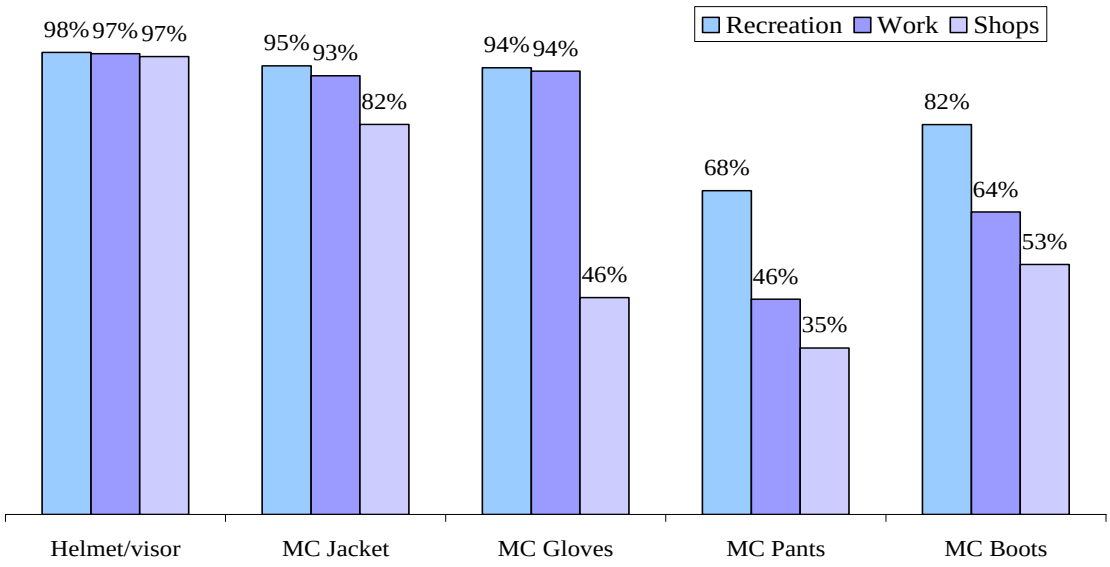


3. Rider usage of protective clothing

Australian surveys of riders' choice of clothing suggest that their decisions do not reflect awareness of the patterns of injury risk that are so well known to researchers (de Rome et al, 2004; de Rome, 2006).

In 2006, a survey of 1,300 Australian motorcyclists asked riders to choose from a list, the protective clothing items they wore the last time they: went on a recreational ride; rode to work; and went on a short trip to the local shops.

Figure 3. Riders usage of motorcycle protective clothing, 2006.



The results found that while virtually all riders wear a helmet and motorcycle jacket, they were least likely to wear protective clothing on their legs.[2] While it was not unexpected to find that many riders did not wear full gear when going on a short trip to the local shops, it was interesting to note that they were more likely to wear full gear when on a recreational ride than when riding to work. Only 64% wore motorcycle boots when commuting to work compared to 82% on recreational rides. Only 46% wore motorcycle pants to work compared to 68% when on recreational rides. They were also almost half as likely to wear pants with leg armour when commuting (17% vs 32%).

The question is whether the differences reflect choices driven by fashion or function. Do these riders believe that they have a greater need of protection on recreational rides than when they are commuting to work? Is the use of protective clothing on recreational rides more of a fashion statement to look the part?

Conversely could the reduced use of protective clothing when commuting be due to a perception of lower risk or to the need for clothing that is more appropriate to be worn in

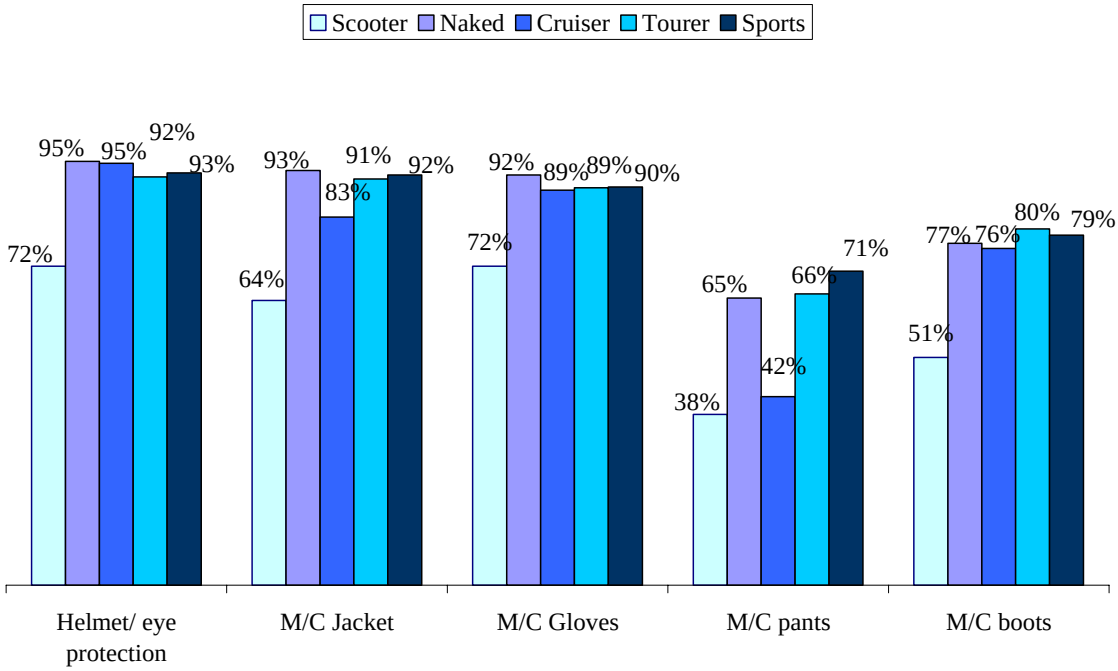
[2] The wearing of an approved, properly fastened helmet is mandatory for motorcycle riders in all states in Australia.

the workplace? Protective clothing is often stylistically inappropriate or uncomfortable for general day wear once the rider has arrived at their destination.

The pattern of usage also varied with the class of motorcycle ridden. Scooter and cruiser riders were least likely to wear high levels of protective clothing. Where high level of protection is defined as helmet with eye protection, motorcycle specific gloves and boots, and motorcycle jackets and pants with impact protectors (Unpublished data, de Rome, 2006). Riders of sports, tourer and naked motorcycles had the highest levels of protection.

Figure 4 shows the proportion of riders by class of motorcycle and whether they wore high levels of protection to each part of their body when on recreational rides.

Figure 4. Protective clothing worn on last recreational ride.



Cruiser riders were most likely not to wear motorcycle pants and were also less likely to wear a motorcycle jacket with impact protectors compared to other riders with the exception of scooter riders.

While there were only 39 scooter riders in the sample, the pattern of their usage is consistent with other work (de Rome et al, 2003). Scooter riders were most likely to wear an open face helmet without visor or goggles. They were also least likely to wear motorcycle protective pants or boots.

This is perfectly understandable in the fashion sense, because scooters are promoted by the industry as machines that do not require the rider to wear protective clothing. For examples, see magazine editorial photographs and advertisements for (e.g. Bolwell, Honda, Hawk) in Two Wheels Scooter, 2005. However we have found no evidence that scooter riders have a lower crash risk than other classes of motorcycle.

The reasons other riders do not wear appropriate protection, particularly on their legs is less clear. However, it may also be linked to the different images associated with different styles of motorcycle. Motorcycle clothing tends to be designed to suit particular

styles of motorcycle and therefore specific sectors of the motorcycle market.

An informal review of advertisements for motorcycle apparel in Australia suggests that the motorcycle clothing market is segmented for different styles of road riding. Clothing that is promoted as providing injury protection tends to be styled in the image of the race track and is aimed at sports bike riders. Clothing that provides protection from the elements tends to be touring oriented. There is relatively little motorcycle protective clothing that is suitable in terms of fashion or convenience for general road riders, cruisers, commuters or scooter riders (de Rome & Stanford, 2006).

4. Comfort and protection from the elements as a safety issue

Protection from the weather is a significant safety issue. Physical stress due to heat, cold or discomfort is tiring and distracting. A relaxed alert rider is less likely to be involved in a crash than someone who is numbed by cold, fatigued by heat or distracted by discomfort.

Cold stress

Feeling cold can affect a motorcyclist in three crucial ways. The most obvious is a loss of feeling in the hands and feet that affects the rider's ability to operate the controls. Feeling cold or uncomfortable is also stressful and tiring, which may place the rider more at risk of crashing because they are less alert and reactions may be slowed. Finally there is evidence that a rider's lower core temperature may affect decision making and increase emotional responses such as anxiety, irritability, aggressiveness, or detachment (Woods, 1986).

Insulation and wind proofing are the keys to avoiding cold stress. The principle of insulation is to allow a thick layer of air between the rider's body and the outer layer of clothing. Close fitting openings (neck, wrists and waist) and covered zippers and other fastening points prevent wind entry and heat loss and are essential to maintain the warmth of the air layer. Clothing that is too loose may also result in heat loss from wind buffeting that forces the warm air out.

A third of the body's heat is lost from the neck and face area, but these areas can be protected by the use of a full face helmet with a visor and a neck sock. Insulated boots and gloves can keep the warmth in the feet and hands. However, this will not be enough if the body is cold, because the brain will restrict blood flow to the extremities in an effort to maintain core temperature. If a rider's body is cold, then their hands and feet will also be cold. The shins of a rider are very exposed to cold; if the shins become cold this will affect blood flow to the feet and therefore the warmth of their feet. Numb feet can seriously affect the rider's capacity to operate controls.

Cold stress can also result from wind chill when wearing damp clothes, because, as the wind evaporates the moisture, it draws the heat from the body.

Wet stress

In addition to being uncomfortable, wet clothing can rapidly chill a rider because it draws heat away from the body. Water conducts heat much faster than air, which means a rider will get cold, much quicker if they are also wet. Wet clothing is a particular problem for motorcyclists because of the additional effects of the wind chill factor. The wind chill factor means that for every 5 km/h wind speed, the surface temperature drops 5 degrees.

Leather does not provide good rain protection because it absorbs water. Most modern textile suits do have some water proof or water resistant properties, however riders usually need to add another layer to be protected from rain.

Wet weather gear is essential, but riders also need to be aware that rain is not the only source of wet stress. Clothing that is wet from perspiration will also draw heat away from the body.

The key to keeping comfortably dry is to have waterproof breathable clothing. Lightweight roll up PVC or plasticised nylon over-suits are waterproof, but not breathable. This means that although they keep the rain out, they quickly become very uncomfortable because they keep perspiration in. This causes accelerated heat transfer resulting in overheating in hot weather and rapid cooling in cold weather.

Heat stress

Many motorcyclists choose not to wear protective clothing in hot weather because it can be hot and uncomfortable. However, in addition to the injury risk to exposed skin in a crash, uncovered skin also absorbs heat directly from the sun causing dehydration leading to fatigue as well as sunburn.

Protective clothing can be designed to overcome some of these problems. Just as insulation is the key to avoiding cold stress, ventilated cover is the key to avoiding heat stress. The idea is to allow wind to flow through the clothing over the skin to evaporate sweat. Air entry points though vents or mesh panels should be on the forward facing parts of the body with maximum air pressure, but should not compromise impact protection.

Light coloured outer layers of clothing can also be selected that will reflect rather than absorb infra-red heat from the road surface.

Noise or vibration stress

Noise and vibration can also cause stress resulting in fatigue and distraction for motorcyclists. Sustained noise over 90db (A) can result in permanent hearing damage, as well as minor pain which is very tiring. In one study, a researcher found that 27% of riders reported noise stress and 22% reported vibration stress (Robertson & Porter, 1987).

Protective equipment can assist to reduce noise stress. The fit and design of helmets and visors can reduce or increase the noise produced by airflow around the head. Ear plugs can also be used to reduce noise provided that they do not also reduce the rider's awareness of their riding environment. Clothing should be chosen that will not flap or vibrate in the air stream while riding, particularly near the head. There are also some boots and gloves in the market which provide protection from vibration though gel or foam in the areas in direct contact with the motorcycle.

Discomfort Stress

It is a basic requirement of all protective clothing is that it should provide a degree of protection without interfering with the rider's ability to ride safely. Riding is an athletic pursuit, so clothing must move freely with the body. The weight, flexibility, temperature control and fit of clothing can all contribute to making the rider more or less comfortable. Protective clothing should fit without constriction. If it is too tight, it may constrict blood flow causing numbness. This is particularly important for the feet, wrists and hands.

Even with the best gear, riding places a strain on the body which must be managed to maintain alertness. Sitting in the same position with limited movement for extended periods of time is unnatural and can lead to muscle stiffness resulting in discomfort, fatigue and loss of concentration. Riders should be encouraged to take regular breaks during long journeys to stretch and revive to avoid fatigue.

5. Conspicuity – drawing the attention of other drivers

In a survey of NSW drivers, 55% reported having at least one experience of having seen a motorcyclist only at the last minute when they were changing lanes. What is more worrying is that only 6% of these same drivers nominated changing lanes as a time when they should watch out for motorcycles (Benton, 2002).

Research into motorcycle crashes shows that the other driver is at fault in about 70% of motorcycle crashes with other vehicles (RTA, 2002). In many of these crashes the driver will say they simply didn't see the motorcycle until it was too late. (SMIDSY - Sorry Mate I Didn't See You).

The situation may be getting worse. In the past, the driving landscape was made up of 95% cars and station wagons. Vulnerable road users such as pedestrians, cyclists and motorcyclists stood out as they were head and shoulders above the roof line of most traffic. The increasing proportion of taller vehicles (e.g SUVs) has changed the driving landscape so that it is harder to see and be seen across traffic.

There is some evidence that what a rider wears can make a difference some of the time although the evidence from different studies suggests that this is highly dependent on the visual environment. The rider needs to be within the other driver's line of vision and the clothing must stand out against the background.

A summary of European research into safety measures for motorcyclists concluded that florescent clothing is effective during daylight, but not against a bright background. They also found that retroflective clothing gives little improvement at night (Noordzij et al, 2001).

A recent New Zealand study, found that riders wearing any reflective or fluorescent clothing had a 37% lower risk than other riders. Riders wearing white helmets had a 24% lower risk than those wearing black helmets (Wells et al, 2004). The latter may also be due to the association with police motorcyclists who wear white helmets in New Zealand.

Failure to see the motorcyclists was the primary contributing factor in 37% of all motorcycle crashes investigated in the MAID Study (ACEM, 2004). Although the researchers found no apparent contribution of garments to the conspicuity of the rider in 65% of crashes, they did report that dull or dark clothing may have decreased conspicuity in 13% of cases.

6. Standards for motorcycle protective clothing

A review of the literature found little objective information that riders could apply in selecting protective clothing products. Riders are largely dependent on the advertising claims of manufacturers or product reviews by magazines. Until recently there was no means of providing an objective assessment or comparison of the likely protective performance of any motorcycle clothing products.

The situation has changed with the development of standards for motorcycle protective clothing in Europe. Under European law, any clothing claiming to provide protection from injury must be tested and labeled as complying with the relevant standard.

This is a general European law that requires standards for all safety equipment not just for motorcycle apparel. Under the directive, a product can only be described as "protective" if it provides protection from injury, the term cannot be applied to products that provide protection from the weather.

The European Directive on Personal Protective Equipment was made law in 1989, but it took some time for the standards for motorcycle clothing to be developed. The first standard to be issued for motorcycle gear was for impact protectors, which was released in 1997 (EN 1621-1). Standards have since been issued for gloves, boots, jackets and pants and back protectors. Each has a different number and clothing that complies must have been tested and labeled with the CE mark and the appropriate standards number.

The development of the standards has provided objective tests for measuring the protective performance of motorcycle clothing products. The tests are largely based on the work of Roderick I. Woods who published a specification for motorcycle protective clothing in which he defined the injury risk and protection requirements for each part of the body (Woods, 1996). See figure 5.

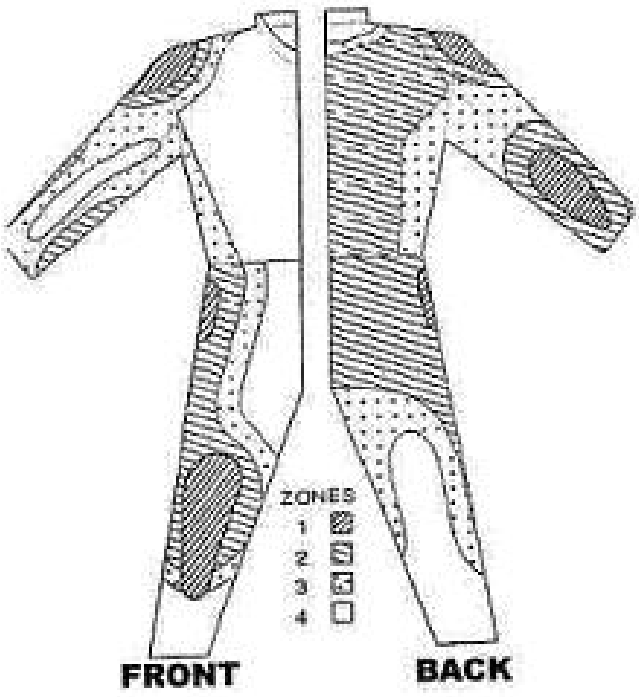
Figure 5. Injury risk zones (Woods, 1996)

Zone 1 High - needs impact protectors & high abrasion resistance

Zone 2. High - needs high abrasion resistance

Zone 3. Moderate - moderate abrasion resistance

Zone 4 Relatively low risk.



The Standards specify the test process and equipment upon which they must be performed. The tests measure performance in relation to:

1. Abrasion resistance to determine how long the material will last when being abraded against the road surface.
2. Burst strength to ensure that seams, fastenings and the material itself will not split open on impact.

3. Tear and cut resistance, required to ensure the material cannot be cut, penetrated or torn by sharp objects in a crash.
4. Impact resistance is required to slow down the rate of transfer of forces in an impact. Protection is required over specified high impact areas of the body and must remain in place during an impact.

While these standards are only enforceable in Europe, their development has significant implications for non-European markets. For the first time consumers have a means of objectively assessing how individual products would perform in the ultimate test of a crash. Applied by independent consumer organizations, the outcome has been to reveal serious failings in the safety performance of many of the products currently available in the European market.

For example, in one study of 18 leather suits tested by the British magazine "Ride" in August 2004, 7 of the suits scored 5 or less out of 10 for abrasion, 10 suits scored 5 or less on the burst test, 9 scored 5 or less on the impact test, 8 scored 5 or less on the tear test and 2 had zip failure (Crick, 2004 b).

None of these failings could have been reliably predicted by visual inspection or reliance on brand name. The results indicate that neither brand name nor cost can be used as indicators of protective quality. The most expensive suit from a world renowned company was rated second last in the rankings, whereas one of the cheapest suits was rated third best. Comparable tests of textile jackets, gloves and boots have also found the majority of those products do not perform well (Crick, 2004 a, 2004 c & 2005).

Similar independent tests have been conducted by consumer groups in the UK over the past ten years. From a comparison of such tests, over the intervening period, it is apparent that manufacturers have responded to calls for better protection. Most European manufacturers now include CE Standard impact protectors over the knees, hips, elbows and shoulders. Cotton padding or comfort foam is no longer acceptable.

The abrasion resistance scores, particularly for textile jackets, have improved significantly over time as new materials and new methods of construction have emerged. However, quality of construction remains a weak point and many of the tested suits (leather and textile) continue to fail on seam strength and material burst resistance. The frustration is that the results suggest that, in many cases, only relatively minor adjustment to production methods could achieve compliance and produce protective products that are fit for the purpose.

The absence of any equivalent standards outside of Europe mean that motorcycle protective clothing can be sold in other markets without a requirement, nor any means, to justify claims of providing protection from injury. Given the high level of failure of reputable European products when tested against the European standards, there is no reason to assume that products by other manufacturers would perform any better.

It is perhaps unrealistic to expect the motorcycle apparel industry to take a lead in raising standards for their products in the absence of demand from their markets. Consumers have been largely uninformed and undemanding, perhaps because the major source of information for riders is through motorcycle magazines, which are dependent on advertising for their revenue.

In Australia and New Zealand a number of steps have been taken to address these issues. Web based consumer guides on motorcycle protective clothing have been developed to enable riders to make more informed purchasing decisions and to demand assurances on the protective quality of the gear they buy (de Rome, 2002; de Rome, 2004).

Strategies have also been undertaken to inform the local motorcycle apparel industry about the existence of the European standards and the implications for the local industry. The availability of the standards also has implications for traders' duty of care under Australian consumer protection law (Trade Practices Act, 1974). Under this law traders can be held liable if their goods are not fit for the purpose for which they were sold.

7. Conclusion

We know which parts of the body are most likely to be injured in a motorcycle crash. We know that perhaps half of all motorcycle injuries could have been reduced or prevented by the use of effective protective clothing. We also know how to manufacture motorcycle clothing that will provide some protection to prevent or reduce injuries. There are standards and objective tests that can be used to ensure the protective performance of motorcycle clothing. Consumer confidence in the performance of these products is essential if riders are to be encouraged to invest in protective motorcycle clothing. A quality assurance or standards system independently assessed or monitored by consumer protection agencies will be essential if that confidence is to be achieved. The adoption of the European Standards as international standards could regularize the industry and provide certainty for manufacturers and motorcyclists alike.

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