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Validation of the principles of injury risk zones for motorcycle protective clothing

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ABSTRACT

Introduction: The distributions of motorcycle crash impacts and injuries were compared to the four impact risk zones and protective performance specified in the European Standard for motorcycle clothing (EN 13595). *Methods:* Crashed motorcyclists' (n = 117) injuries and clothing damage were categorized by body area into the four risk zones. Three levels of protection were defined: protective clothing with impact protection, protective clothing only and non-protective clothing. *Results:* The distribution of impact/injury sites corresponded to the predictions of EN 13595, with the proportion of all injuries decreasing from 43.9% in Zone 1, to 18.0%, 16.7%, and 11.5% in Zones 2 to 4, respectively. Protective clothing modified the distribution of injuries with substantially more injuries (OR = 2.69, 95% CL: 20.1–3.59) at unprotected impact sites. *Practical application:* These findings support an appropriate framework for determining performance specifications for the manufacture of motorcycle clothing that will effectively reduce the risk of injury in crashes.

1. Introduction

Motorcyclists represent an increasing proportion of road crash casualties globally due to the rapid expansion of the motorcycle market over the past decade (Rogers, 2008). While road safety initiatives have reduced the casualty rates for vehicle occupants, there have been fewer advances in motorcycle safety (Ameratunga, Hijar, & Norton, 2006). Current trends suggest that motorcyclists are likely to comprise an increasing proportion of road users killed or disabled due to crashes (Peden et al., 2004).

There is ample evidence of the protective benefits of motorcycle helmets, but less attention has been paid to protective clothing as a potentially significant safety measure (Crompton et al., 2009; Hurt, Ouellet, & Wagar, 1981; Liu et al., 2008). Prime and Wood (1984) first identified the abrasion resistance of materials and the integrity of fastenings and seam construction as critical to the performance of clothing in motorcycle crashes. Based on these findings, Woods (1994) developed tests of abrasion, tear, and burst resistance of clothing to replicate the types of crash damage observed. In subsequent research he used 100 crash-damaged leather suits to plot the distribution of crash impacts and types of damage. The results revealed distinctive patterns of damage associated with different parts of the body, which he classified by level of exposure in crashes into four risk zones (Woods, 1996). This body of work was published as the Cambridge Standard for Motorcycle Rider's Clothing under which injury protection is provided through two complementary functions: attenuation of impact force by shielding high risk areas and, the protection of soft tissue by abrasion resistant materials (Woods, 1999). The standard provided test requirements and performance specifications for the level of abrasion, tear, burst ,and impact resistance required in each risk zone. The levels of protection required from Zone 1 to Zone 4 reduce progressively. Fig. 1 illustrates the areas covered by each zone. Zone 1 corresponds to the shoulders, elbows, hips, and knees which are subject to severe impacts and abrasion and require fitted impact protection and high abrasion resistance. Zone 2 is subject to severe abrasion and also stress damage, whereas Zone 3 has only moderate abrasion risk and Zone 4 is at low risk of any road contact. The specifications subsequently formed the basis of EN 13595 the European Standard for motorcycle protective jackets and pants (CEN, 2002).

The European Standards have provided benchmarks for industry across the international market, resulting in a new generation of protective clothing products, but few manufacturers submit their products for testing and consequently garments accredited to EN 13595 are relatively rare in the Australian market place (de Rome, 2006). As a result the effectiveness of compliant products has not been evaluated nor have

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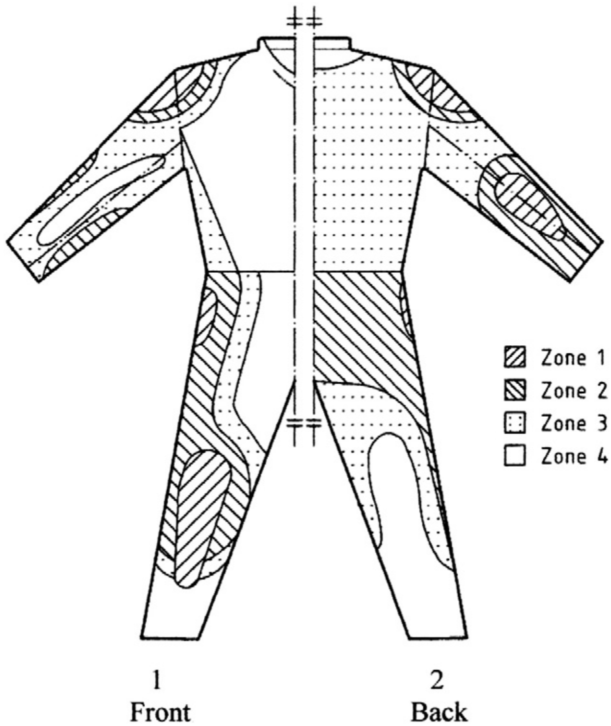

Fig. 1. Motorcyclist's injury risk zones (CEN, 2002).

the specified test performance levels been validated in real world crashes. This paper is an extension of a recent Australian study that found strong evidence of reduced risk of injuries and hospitalization following motorcycle crashes when riders had been wearing motorcycle protective clothing, particularly when fitted with body armor (de Rome et al., 2011). Subsequent analysis of that data, looking at road contact damage and abrasion marks on the riders' clothing, found the distribution of impacts to be largely consistent with those predicted by Woods' risk zones (Meredith, Brown, Ivers, & de Rome, 2013). The current analysis examines the distribution of those riders' injuries to determine whether injuries follow a similar pattern to the risk zones, and the extent to which the distribution and type of injuries across risk zones was moderated by the presence of protective clothing.

2. Method

2.1. Study design and participants

This was a cross-sectional analytic study of data from motorcyclists, injured and uninjured who crashed in the Australian Capital Territory (ACT) between June 2008 and July 2009. Eligible participants were residents of the study area, aged 17–70 years, who were riders or passengers involved in motorcycle crashes on public roads within the ACT. The current analysis relates only to those injured motorcyclists who attended the Canberra hospital and whose clothing was available for inspection. Other aspects of the study have been published elsewhere (de Rome et al., 2011, 2012; Meredith et al., 2013).

Motorcyclists were excluded if they scored <13 on the Glasgow Coma Scale (GCS), sustained severe head injuries (3+) or spinal injuries (4+) on the Abbreviated Injury Scale (AIS), or were otherwise unable to provide informed consent (AAAM, 2005; Teasdale & Jennett, 1974). Those who agreed to participate were interviewed face-to-face within two weeks of the crash. The interview format was based on the OECD methodology for motorcycle crash investigation (OECD, 2001). Comprehensive information was collected from participants about the circumstances of the crash, type and speed of impact, injury details, and type of clothing worn. Clothing was also inspected and any evidence of crash impacts were recorded and photographed. Participants' medical records were used to corroborate interview reports on injuries and admissions details.

The current dataset comprises multiple instances of crash impacts as evidenced by road marks or damage to clothing or injury from each participant. Each damage or injury site was classified according to its location in the risk zones (see Fig. 1) specified in the European Standard for motorcycle clothing (CEN, 2002). Injuries were matched as closely as possible to the area covered by the relevant risk zone. To ensure the distribution of impact sites included all possible contact locations, sites were also included where injury had occurred but clothing was undamaged or not present. In some cases it was not possible to precisely locate injuries or clothing damage according to the risk zones due to lack of information in the interview or medical records. This included injury to internal organs within the thoracic and abdominal cavity. These unclassified injury and damage locations, as well as injury sites for which the presence of motorcycle designed protective clothing could not be verified ($n = 98$) were excluded from the regression analysis.

Clothing was classified as motorcycle protective clothing ‘PPE’ if labeling indicated that it was designed for motorcycle use and it was constructed of materials known to be used for abrasion resistance. Otherwise it was classified as ‘non-protective clothing.’ It was also classified according to whether or not impact protection (CEN, 1998) was incorporated to provide impact protection as required in Zone 1 under EN 13595. A variable describing level of protection was then constructed. For Zone 1, three levels of protection were defined: 1) PPE + IP = protective clothing with impact protection incorporated, 2) PPE-only = protective clothing without impact protection, and 3) unprotected = non-protective clothing or unclad. In Zones 2–4, where impact protection is not required, two levels were defined: 1) PPE = motorcycle protective clothing or 2) unprotected = non-protective clothing or unclad.

Outcome factors were the type and distribution of injuries to the limbs and torso. Injuries to heads, hands and feet were not included in this analysis. Injuries were classified as: abrasions, cuts and lacerations, contusions, burns, fractures, dislocations and other soft tissue injuries (e.g. sprains and not further specified injury to ligaments and muscles). For the multi-variable analysis: abrasions, cuts, lacerations, and burns were combined into the single category of open wounds; fractures, sprains, and dislocations were combined as musculoskeletal injuries.

2.2. Statistical analysis

The findings are presented descriptively in tables with Mantel–Haenszel chi-square used to determine any trend in proportions across zones. Logistic regression was used to compute odds ratios, associated 95% confidence intervals for injury associated with impacts within each injury risk zone by level of protection using SAS V9.2.

3. Results

Data were obtained from 117 participants. The majority wore motorcycle designed jackets (76%) and gloves (80%), but fewer motorcycle designed pants (27%) or footwear (31%). Impacts to the torso, upper and lower limbs were documented consisting of 779 points of impact damage to clothing and a further 432 injuries that were not directly associated with clothing damage. Just over half of all impact sites (54%) were protected by motorcycle designed clothing constructed of either abrasion-resistant fabric (58%) or leather (39%). All but 16% ($n = 192$) of impact/injury sites were able to be classified by risk zone. Unclassified sites accounted for 42% of non-injury impact sites and 9% of injury sites.

Over a third of impact sites were in Zone 1 (35%), which accounted for 44% of all injury and 15% of non-injury impact sites. The proportion of impact damage and injury sites decreased in sequence from Zones 1 to 4 (X^2 (1, N = 970) = 144.24, $p < .0001$). Table 1 shows the distribution and odds ratio for injury associated with impacts in each risk zone.