DISTRIBUTION AND TYPE OF DAMAGE TO CLOTHING WORN BY MOTORCYCLISTS: VALIDATION OF THE PRINCIPALS OF EN13595

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ABSTRACT

While the use of protective clothing has been shown to reduce the risk of injury for motorcycle riders, not all protective clothing performs the same in crashes. A European standard for motorcycle protective clothing (EN13595) was released in 2002. Riders that use clothing approved to this Standard should expect good protection. This standard specifies four zones in motorcycle clothing with different levels of protective qualities and four different test methods for assessing abrasion, burst, cut and tear damage resistance. High frequency impact areas are labelled zone 1 and include the elbows, knees, hips and shoulders. Zone 4 has the lowest expected frequency of impact.
This project examined damage location and type in clothing worn by riders following a crash to establish the distribution of impact points and validate the principals indicated in EN13595.
Data from 117 crashed motorcycle riders collected during crash investigation were examined. This data included medical data and clothing inspections, and contained 576 cases of clothing damage. To ensure the impact point distribution included all possible contact locations, an additional 433 distinct injury locations were examined where injury had occurred but no damage was observed or no clothing was present at that location. Descriptive techniques were used in the analysis.
The majority of damage occurred in areas covering the extremities or pelvic girdle (93%) with most occurring on the wrists and hands (18%) and the ankles and feet (18%). Clothing regions covering the shoulder (10%), forearm (10%), elbow (9%), thigh (7%), lower leg (6%) and pelvic-hip (5%) were also frequently damaged. Other body regions contributed only 8% of damage seen. Analysis of the injury where no damage occurred demonstrated a similar distribution of impact. The most common types of clothing damage were abrasion, accounting for 69% and torn material which accounted for 26% of all damage. Further, the majority of material abrasion and tearing occurred in regions corresponding to zone 1, followed by zone 2, 3 and then 4. There were very few instances (3%) of burst and cut damage.
The results are in agreement with the general concept of the zoning used in the European standard. However, these results indicate that minor adjustments may be warranted. In particular, the number of impacts to the forearm and lower leg suggest that these regions might be better protected by considering the whole regions as Zone 1or 2 rather than the multiple regions as currently indicated in the Standard. However the subjective nature of determining the zone in which damage (and/or injury) occurred limits these findings and any others that attempt to validate the zone principals using real world data. Further validation requires consideration of the severity of impact at different zones.
This work confirms the validity of the principals of EN13595 but indicates room for modification, and will be of interest to those developing regulatory and consumer assessment protocols for motorcycle protective clothing.

INTRODUCTION

Motorcyclists face a higher relative risk of serious injury than car occupants despite the fact that motorcycle usage only accounts for one per cent of vehicle kilometres travelled. These figures have been steadily increasing in recent years and may be linked to the increase in sales growth for motorcycles [1-4]. Motorcycle injuries as a result of a crash have been reported to cause a significant cost to the public health system [5].
The most common form of injury in motorcycle crashes has been shown to be skin abrasions, lacerations and contusions [6-8] and are primarily due to contact with the roadway or road side [6]. Additionally, it has been shown that the majority of

injuries involve sliding, being dragged, tumbling or rolling to the final position. Protective clothing is suitable to provide protection for these types of movements [9].

The use of protective clothing to reduce soft tissue injuries for motorcycle riders has been the subject of scientific discussion at least since 1976, when Feldkamp and Junghanns [10] reported on protective clothing being associated with a reduction of serious injuries in motorcycle crashes. Since then, there has been increasing evidence of the benefits of protective clothing, particularly in low-impact (<50km/h) crashes [6, 7, 11-21], which are the most frequent type of motorcycle crash [6, 15, 22].

The European standard for motorcycle protective clothing (jackets, trousers and one piece or divided suits), EN13595 [23], was released in 2002 and established the broad technical requirements and performance criteria for motorcycle protective clothing.

The technical basis for EN13595 is largely work conducted by R.I. Woods. Woods examined the location and type of damage seen to 100 motorcycle suits following a crash [24] as well as observing the type of damage seen in samples of clothing on different road surfaces using dummy simulation of motorcyclists impacting the ground following a crash [25].

Four different zones with different levels of protective capabilities were created based on the distribution of damage observed to the damaged motorcycle suits. Zone 1 has the highest expected frequency of impact and hence these areas require impact protectors. Zone 1 regions include the knees, elbows, shoulders and hips. Zone 4 has the lowest frequency of impact and the material in these regions can be used to provide ventilation. The different types of damage to the clothing were observed to be abrasion, cut, tear and burst damage. Based on these results, machines were developed to recreate these types of damage in a laboratory environment [26]. The performance criteria for burst, cut, tear and abrasion resistance were developed from these laboratory studies.

Despite the limited review of real world data and the non-biofidelic dummy simulations conducted by Woods, this work was used to design the test methods and performance criteria included in the European Standard. This project examines the distribution of impact locations to motorcyclists from a sample of real world motorcycle crashes. It compares this impact distribution, and the types of damage seen in their clothing, to the principles incorporated in EN13595.

METHODS

The Gear study [7] involved a 12 month prospective cohort of motorcycle crashes on public roads within the Australian Capital Territory (ACT) and was conducted from June 2008. Eligible participants were residents of the study area, aged 17-70 years who had sustained an injury or required repair of damage to their motorcycle following a crash. Motorcyclists were excluded if they scored <13 on the Glasgow Coma Scale (GCS), sustained severe head (3+) or spinal injuries (4+) on the Abbreviated Injury Scale (AIS), or were otherwise unable to provide informed consent [27, 28]. The 117 cases examined for this analysis included only the cases from the GEAR study in which the participant had been injured and medical records were available.

Potential participants were identified through the two hospitals servicing the study area and participants were interviewed face-face approximately two weeks after their crash. The interview format was based on the OECD methodology for motorcycle crash investigation [29] and information collected included the self-reported type and speed of impact, clothing worn and injury details. The damage and injury details, including location, type of damage and dimensions, were recorded on body outline diagram by the interviewer. The medical records of participants who attended hospital were used to corroborate interview reports on injuries and admissions details. Where possible, photographs were taken of the clothing worn by participants during the crash and compared to interview reports.

From this data, the type of clothing and impact protection worn by the motorcyclists was analysed. Clothing type was classified by whether it was specifically designed for motorcycle use, not designed for motorcycle use or not present at all. Clothing items which were specified as a jacket not designed for motorcycle use included any type of upper garment (e.g. jackets, jumpers and shirts) and was classified by degree of coverage (long or short sleeves). Pants specified as not designed for motorcycle use were classified as long, short or calf length pants. Gloves were classified into whether they covered the wrists or didn't cover the wrists. Information was additionally collected on whether gloves and footwear remained on the riders' hands and feet during the crash. Information was recorded on whether impact protection was worn by the riders on the shoulders, back, elbows, hips and knees; whether this impact protection worn was certified to the European Standard for impact protectors; and whether the impact protector remained in the appropriate position during the crash. The type of clothing material was also analysed and was classified into nine groups: light-weight material (e.g. shirt/t-shirt); waterproof material; medium weight (e.g. denim, cotton knit); abrasion resistant fabric (e.g. Cordura, Kevlar reinforced); leather; a combination of leather and

abrasion resistant fabrics; unknown; none; and other.

Areas of damage to each riders clothing were recorded and analysed. Areas of injury resulting from an impact to the body where clothing was either not present or not damaged were also recorded and analysed to ensure all areas of impact were included. Fractures, sprains, dislocations and avulsions were not included as they are not necessarily representative of the exact location of impact. Skin injuries were classified as abrasions, lacerations, contusions and burns.

Injury details were coded using the National Sampling System (NASS) Occupant Injury Classification (OIC) scheme [30]. The OIC categorizes injury by body region using both the Injury Severity Score (ISS) and OIC regions, and by the aspect of injury, type of injury, Abbreviated Injury Scale (AIS) severity of the injury, organ or system injured, injury source and source of data.

A similar coding method was developed for the purposes of classifying the clothing damage location and type of damage. This included relating the damage location to OIC and ISS body regions, aspect of damage, type of damage (abrasion, burst, cut or tear), depth of damage, clothing system damaged, source of damage and source of information. The type of damage seen to the different clothing items was also analysed.

Impact locations were classified in terms of their relation to the clothing zones as specified by the European Standard. Impact locations were only included if they occurred to the clothing, not to the footwear or gloves and if they had sufficient positional information to classify into a zone.

Descriptive analysis was used to determine the distribution of impact locations with respect to the ISS body regions, OIC body regions and clothing zones. Additionally, descriptive techniques were used to determine the major forms of clothing damage observed and the main forms of skin injury at distinct injury locations. Analysis was conducted using IBM SPSS Statistics 20 [31].

Ethical approval for the Gear study was obtained from the Human Research Ethics Committees (HREC) for ACT Health and Calvary Health Care.

RESULTS

Table 1 summarises the type of clothing worn by the 117 crashed motorcycle riders.

The results indicated that the majority of riders wore jackets which were designed for motorcycle use (76%) as well as gloves designed for motorcycle use (80%). Riders were not as likely to be wearing pants designed for motorcycle use (27%) or footwear designed for motorcycle use (31%).

The majority of the clothing worn was not approved to the EN13595 standard. None of the pants or jackets worn by the motorcyclists were approved to this standard. However, 3% of footwear and 2% of gloves were CE certified.

A majority of riders wore long sleeved upper garments (90%), long pants (96%) and gloves which covered the wrists (66%) while only 20% of gloves worn by riders did not cover the wrists.

Table 2 presents information on the amount and type of impact protection worn by the riders. More than half of the jackets contained impact protection at the shoulders (63%), back (55%) and elbows (62%). Only a minority of the pants contained impact protectors at the hips (9%) and the knees (11%).

Almost half of the shoulder impact protectors (48%) and elbow impact protectors (47%), and almost two thirds of the knee impact protectors (62%) were approved to the European Standard for impact protectors. However, less than 10% of back impact protectors (6%) and hip impact protectors (9%) were approved to the Standard.

The majority of impact protectors were reported by the riders to have remained in place during the crash: shoulders (77%), back (75%), elbows (81%), hips (64%) and knees (77%).

Table 3 illustrates the types and frequency of materials observed in the clothing worn by the 117 motorcycle riders. Abrasion resistant fabric jackets (54%) were more popular than leather jackets (23%) and 15% of motorcyclists wore upper garments made from other light-weight materials. The majority of pants were manufactured from medium weight materials (54%) followed by abrasion resistant fabrics (21%). Most of the footwear (82%) and the gloves (55%) were made from leather.

Table1.
Clothing worn by motorcycle riders during the crash (sample size is n=117 for each clothing type).

	Designed for motorcycle use (%)			CE approved (%)			Length (%)				Remained on (%)		
	yes	no	none	yes	no	unknown	short	calf	long	unknown	yes	no	unknown
jacket	76	24	0	0	92	8	9	n/a	91	0	n/a	n/a	n/a
pants	27	74	0	0	96	4	3	2	96	0	n/a	n/a	n/a
footwear	31	69	0	3	90	7	n/a	n/a	n/a	n/a	87	11	2
gloves	80	10	9	2	80	9	20	n/a	66	5	83	0	8

Table2.
Impact protection worn by motorcycle riders during the crash.
Note: The first column displays the percentage of clothing in which impact protectors were present. Of the impact protectors which were present, the second column displays the percentage of impact protector types worn, and the third column describes whether these protectors remained in position.

	Present (%) n=117			**Type (%)**				**Position remained (%)**		
	yes	no	unknown	CE certified	comfort	other	unknown	yes	no	unknown
shoulders	62	37	1	48	21	29	4	77	16	8
back	55	45	0	6	66	23	5	75	3	22
elbows	62	38	0	47	21	28	6	81	11	8
hips	9	91	0	9	55	27	9	64	9	27
knees	11	89	0	62	23	8	8	77	15	8

Table3.
Types of material worn (sample size is n=117 for each clothing type).

Material	**Jacket** n=117	**Pants** n=117	**Footwear** n=117	**Gloves** n=117	**Total**
light-weight material (e.g. shirt/t-shirt)	18	19	1	0	38
waterproof only	1	2	0	0	3
medium weight (e.g. denim, cotton knit)	7	63	5	6	81
abrasion resistant fabric (e.g. Cordura, Kevlar reinforced)	63	25	4	6	98
leather	27	6	96	64	193
combination of leather and abrasion resistant fabrics	0	1	9	21	31
unknown	1	1	2	8	12
none	0	0	0	11	11
other	0	0	0	1	1

Table4.
Type of clothing worn at the location of the clothing damage and skin injury

Designed for motorcycle use	**Damage (%) n=576**	**Skin injury (%) n=433**
yes	63	37
no	37	54
none	n/a	9
unknown	0.2	0.2

Among the 117 crashed motorcycle riders there were 576 distinct areas of clothing damage and an additional 433 areas of distinct skin injury (see Table 4). This is an average of four skin injuries and five clothing damage locations per rider with a range of 0-22 for both skin injury and clothing damage locations.

Most of the clothing damage (63%) was observed in clothing that had been designed for motorcycle use. Most of the skin injuries observed, where no clothing damage was present, were to body regions where the rider wore clothing not designed for motorcycle use (54%). Only a small amount of skin injuries actually occurred where no clothing was present at the site of the injury (9%).

The distribution of impact locations with respect to the ISS body regions is shown in Figure 1. Clothing damage occurred most frequently on the extremities and pelvic girdle (93%), with only a small amount of clothing damage seen to the abdominal or pelvic contents (4%), the chest (3%) and the head or neck (0.2%).

Investigation into the predominant impact locations (including both clothing damage and skin injury) in terms of the ISS body regions showed a similar distribution to that of just clothing damage. Most impacts still occurred to the extremities or pelvic girdle (90%), followed by the abdominal or pelvic contents (5%) and the chest (4%).

Figure 2 presents the distribution of impact locations according to the OIC body region in which the impact occurred. Wrists and hands (18%) and the ankles and feet (18%) contributed the most to the total amount of clothing damage observed. Clothing regions covering the shoulders (10%), the forearms (10%), the knees (10%) and the elbows (8%) were also damaged frequently. Other regions which had a large number of impacts were the thighs (7%), the lower legs (6%) and the pelvic-hip (5%). Clothing damage covering other body regions contributed only 8% of the total damage observed.

The distribution of all impact locations, including both skin injury and clothing damage locations, was similar to that of just clothing damage locations (see Figure 2). Most of the impacts occurred to the wrists and hands (17%), followed by the ankles and feet (13%) and the knees (12%). Other body regions contributing to the total number of impacts observed were the thighs (9%), the shoulders (8%), the lower legs (8%), the forearms (8%), the pelvic-hip (7%) and the elbows (6%). Impacts in other body regions only contributed 14% to the number of impacts observed.

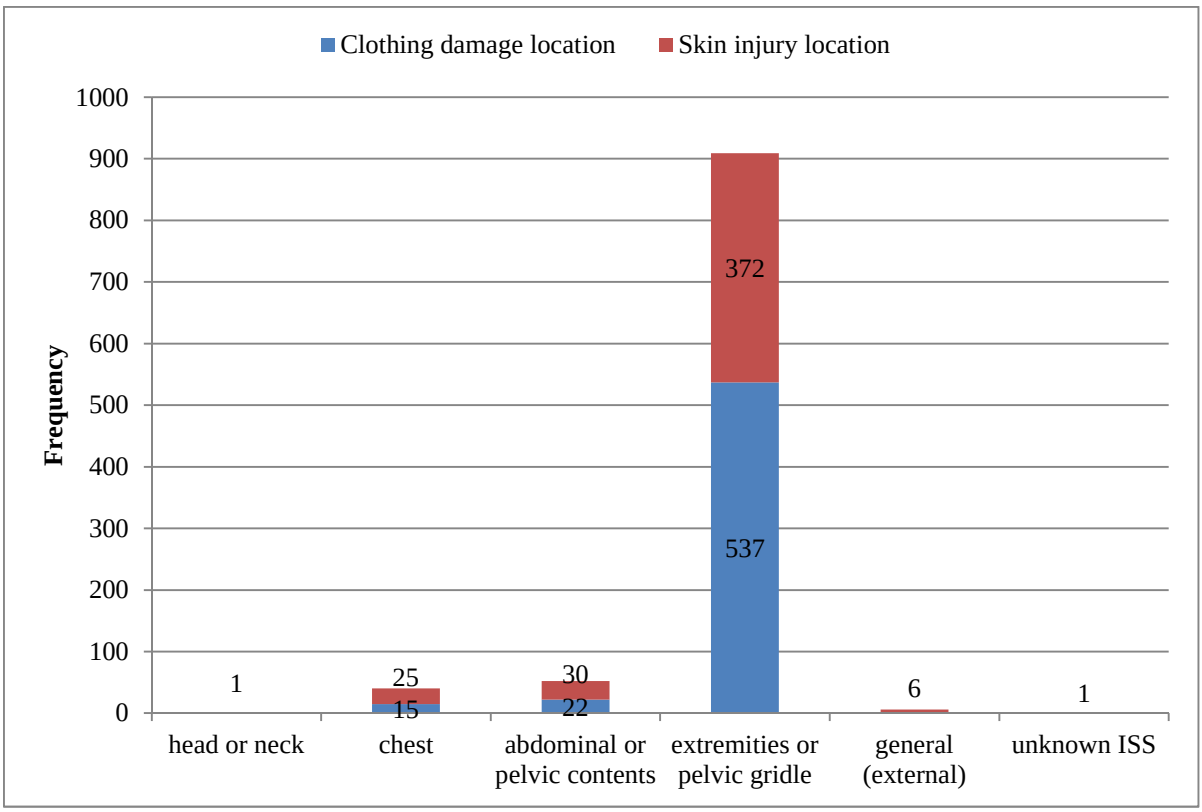

Figure1. ISS body region of all impact locations.

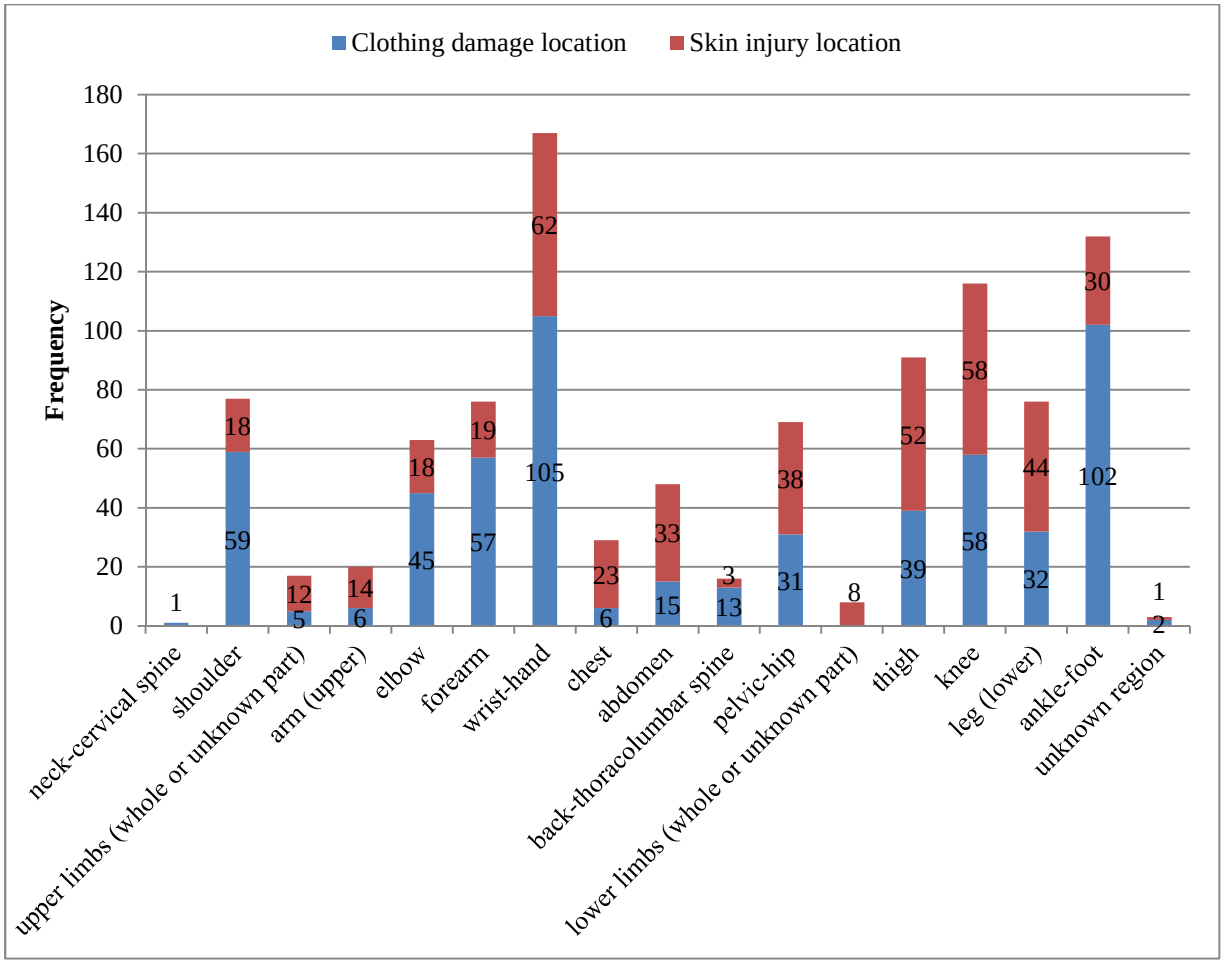

Figure2. OIC body region for all impact points.

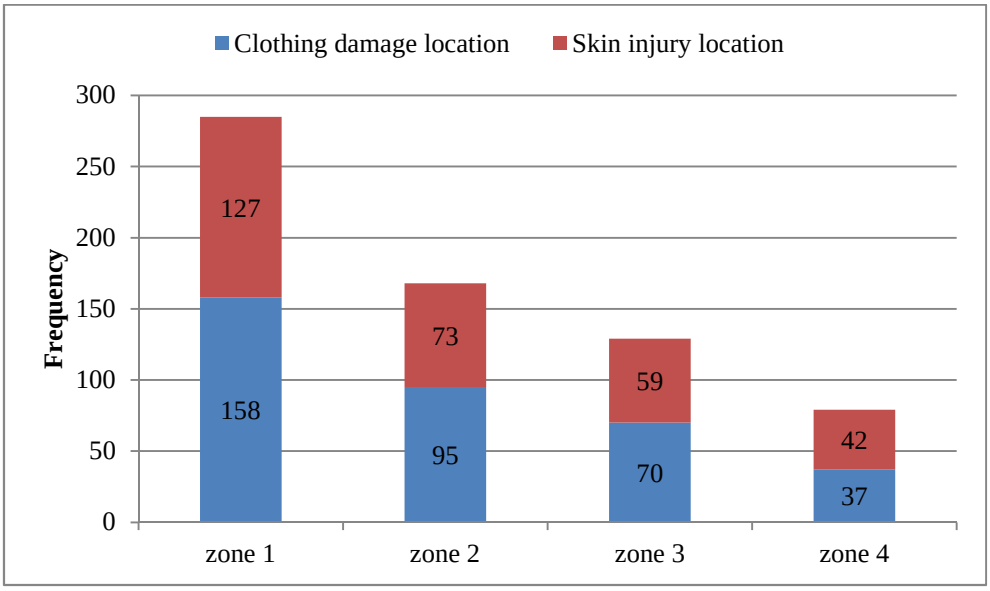

Figure3. Frequency of impacts to the different clothing zones

Figure 3 presents the frequency of impacts to each of the four different clothing zones. There were 661 cases of impact locations (360 clothing damage locations; 301 skin injury locations) which were investigated for the zone location. Impacts occurred mostly to zone 1clothing regions (43%), followed by zone 2 (25%), zone 3(20%) and zone 4 clothing regions (12%).

The distribution of the impact locations with respect to both the OIC body locations and the clothing zones was examined. This impact distribution is shown in Figure 4.

A large number of the forearm impact locations (36) occurred in zone 3 and 30 impacts occurred in zone 2. Most of the impacts to the thigh occurred in zone 2 (64) with a reasonable amount occurring to zone 3 (13) and zone 4 (14). The lower leg impacts occurred mostly to zone 1 (29) and zone 2 (17). There were seven impacts to both the front and the back of the lower leg in zone 4, one impact to the ankle and four impacts behind the knee. Zone 3 of the upper arm also had a large number of impacts with 10 impacts on the front and 6 impacts on the back of the upper arm. The chest and abdomen both had a large number of impacts with 17 impacts occurring in both body regions.

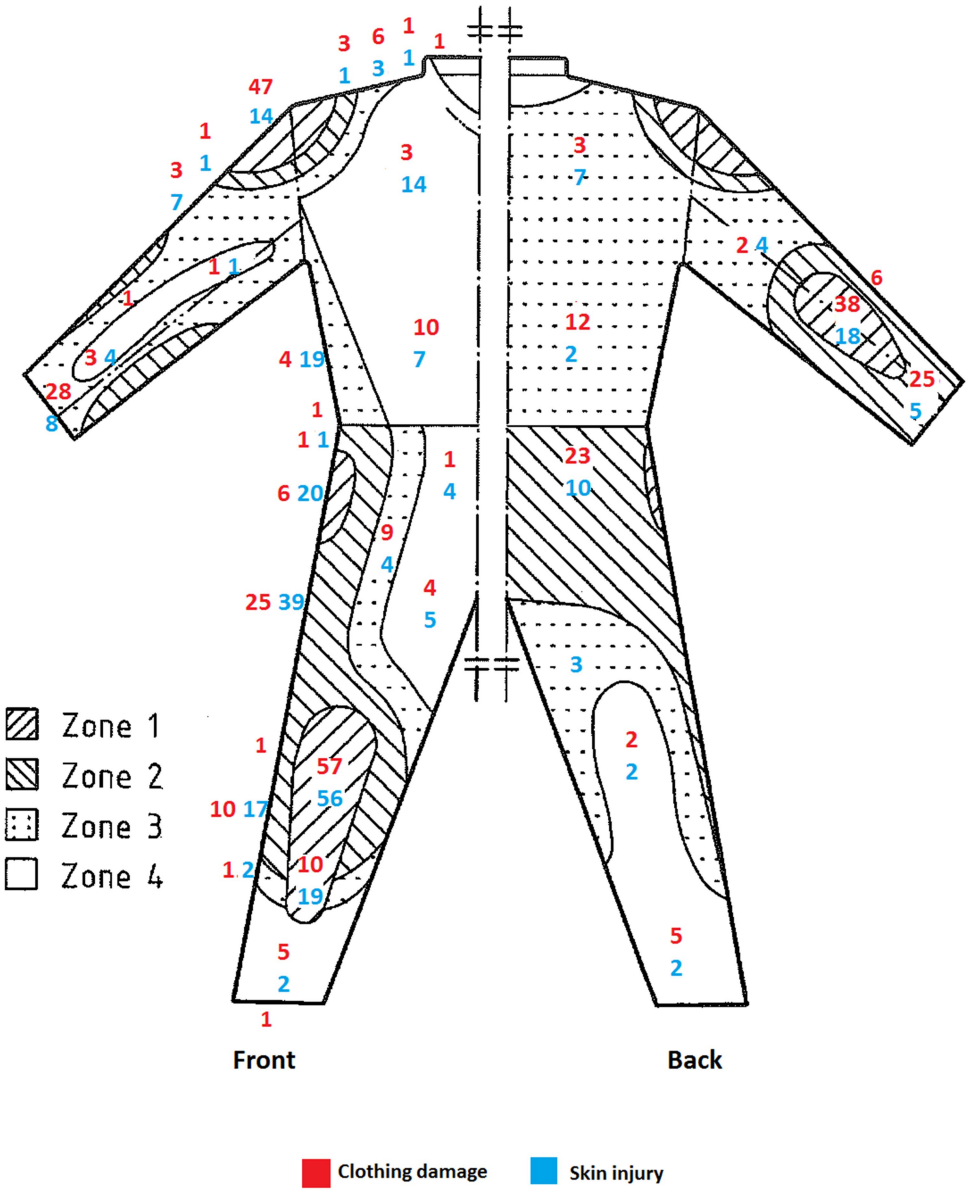

Figure4. Distribution of damage with respect to zones as specified in EN13595.

Clothing damage was classified as one of the four different types of damage specified in the European Standard. These types of damage were: abrasion/erosion of the material, burst-failure of the seams or fastenings, penetration or cutting by a sharp object and torn material.
Figure 5 presents the frequency of the different types of damage which occurred to the clothing. The most common types of damage observed were abrasion, accounting for 69% of the total amount of damage observed, and torn material which accounted for 26% of the total damage. There was little evidence of cut or burst damage to the clothing which accounted for only 3% of the total damage observed.
The frequency of the different types of damage in each of the four clothing zones is presented in Figure 6. The majority of abrasion and tear damage was seen in clothing region zone 1 followed by zones 2, 3 and 4. This was not the case for burst and cut damage, which was more randomly distributed. However, there were not enough cases of burst and cut damage to obtain a clear pattern of which clothing zones these types of damage were occurring in.
The type of damage seen to different items of clothing which were CE marked clothing as compared to clothing items which were not approved to the European Standard is shown in Table 5. There were seven cases of damage to clothing which were CE marked. All seven points of damage were abrasion damage occurring to the footwear and gloves as footwear and gloves were the only CE marked clothing worn. Majority of abrasion occurred to upper garments (36%), followed by pants (25%), gloves (20%) and footwear (19%). Torn material occurred frequently to both pants and jackets. Upper garments were damaged the most (36%), followed by pants (28%). Footwear (18%) and gloves (18%) were damaged less frequently.
There was no CE marked jackets or pants worn. Of the 208 cases of damage seen to jackets, 70% was abrasion damage, and 27% was tear damage. There were 162 cases of damage to the pants, with 61% being abrasion damage and 36% being tear damage.

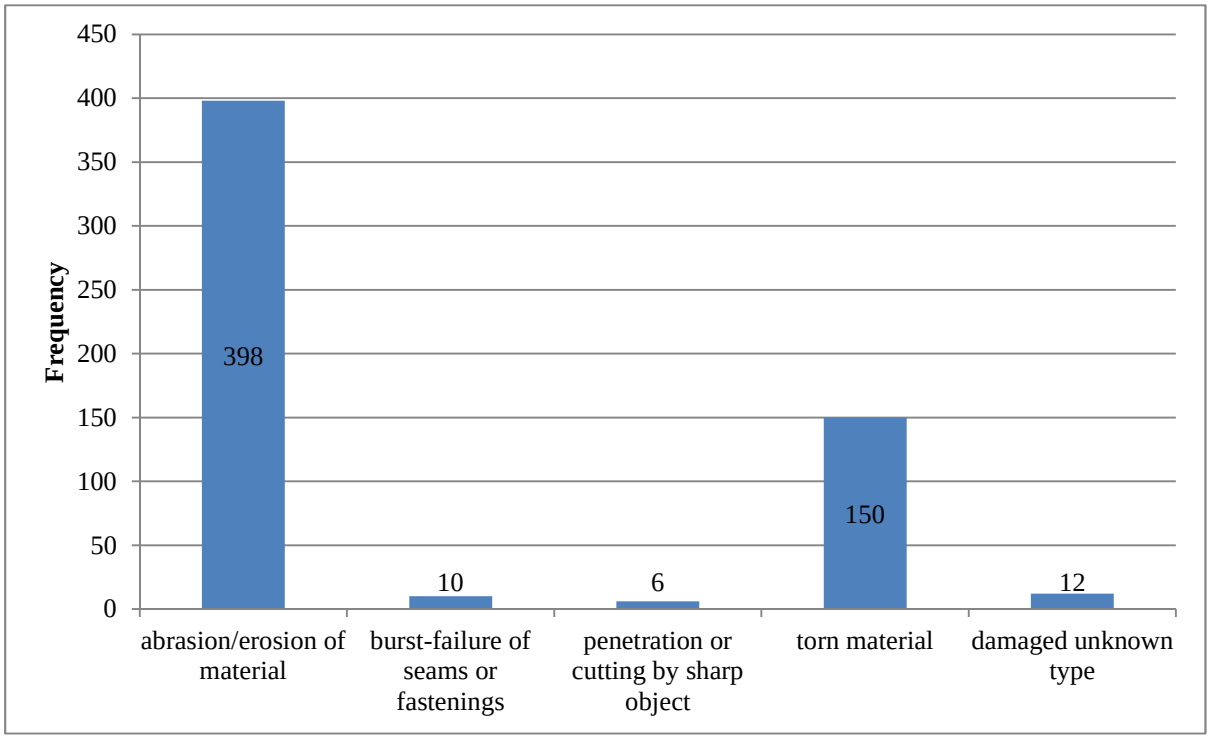

Figure5. Type of damage seen to the clothing

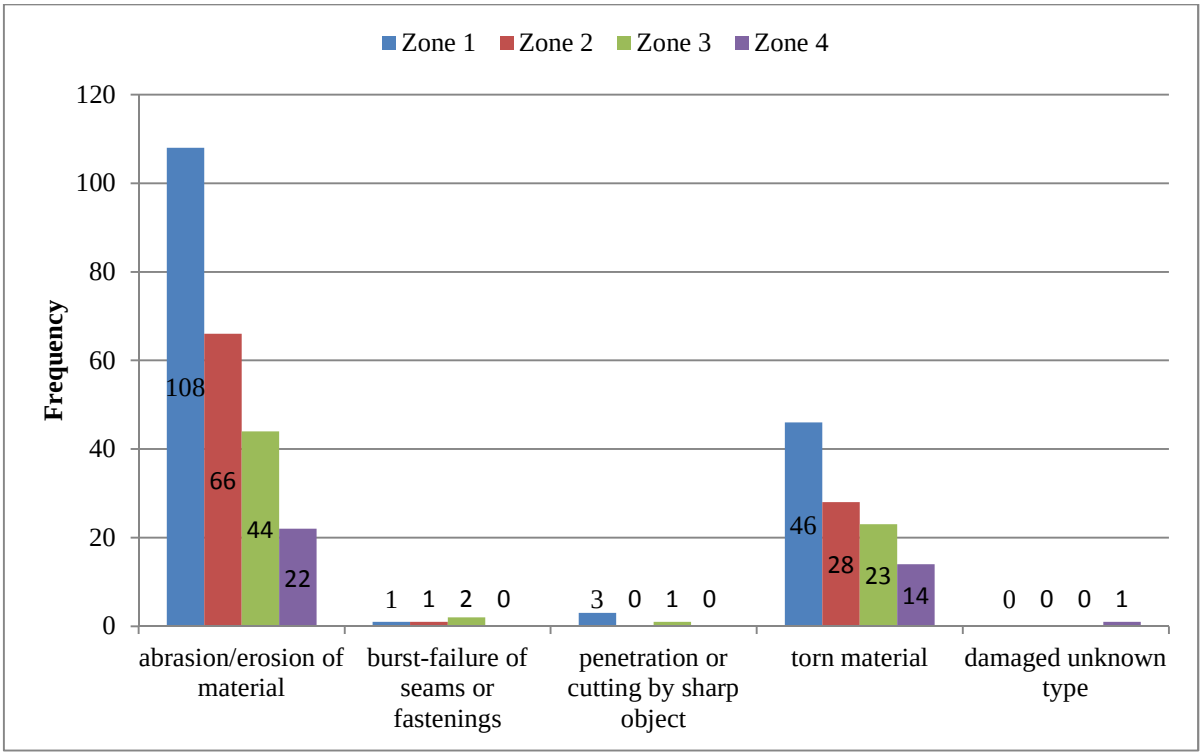

Figure6. Distribution of the different types of damage for the different clothing zones.

Table5.
Distribution of the different types of clothing damage seen to CE approved clothing.

		Clothing type (%) (total number of damage n=576)			
CE marked	**Damage type**	**jacket**	**pants**	**footwear**	**gloves**
yes	abrasion	0	0	1	0.3
	burst	0	0	0	0
	cut	0	0	0	0
	tear	0	0	0	0
	unknown	0	0	0	0
no	abrasion	23	17	11	13
	burst	1	0.2	1	1
	cut	0.2	1	0.3	0
	tear	10	10	3	3
	unknown	0.3	0.2	1	1
unknown	abrasion	2	0.2	1	1
	burst	0	0	0	0
	cut	0	0	0	0
	tear	0.2	0	0.2	0.2
	unknown	0	0	0.2	0
total		36	28	18	18

The frequency of the different types of skin injury occurring to the motorcyclists is shown in Figure 7. The most frequent injury type was contusions (54%) followed by abrasions (31%), lacerations (14%) and burns (1%).

The frequency of the different types of skin injury occurring in the four different clothing zones is displayed in Figure 8. The majority of laceration, contusion and abrasion injury was to zone 1 followed by zones 2, 3 and 4. Burn injuries did not follow this pattern.

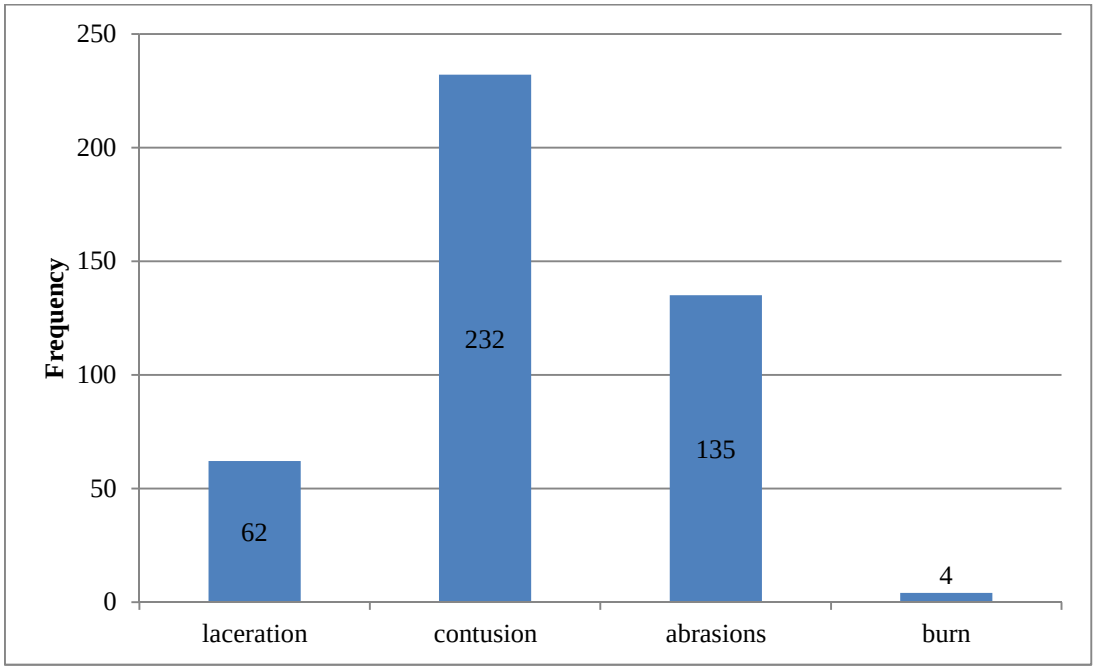

Figure7. Types of skin injuries occurring to motorcyclists.

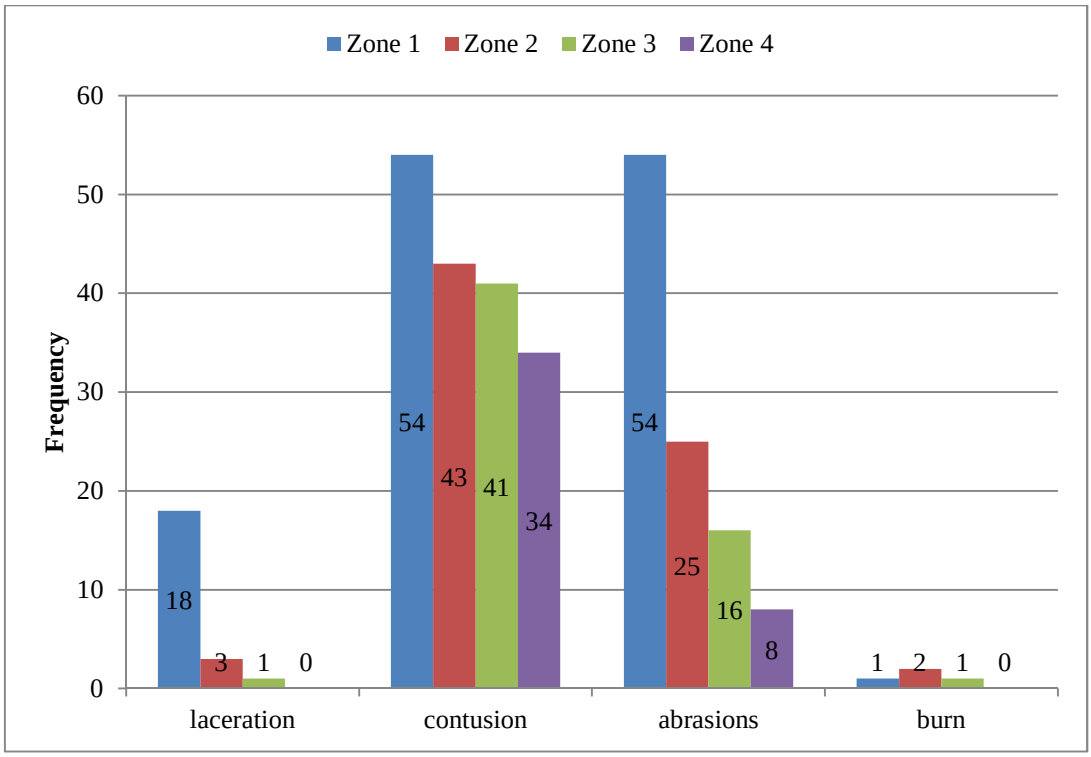

Figure8. Distribution of skin injury to the four clothing zones.

DISCUSSION AND LIMITATIONS

This study has provided a detailed examination of the distribution of impact locations to motorcycle riders during a crash as well as investigating the type of damage observed to the motorcycle clothing. The impact distribution to motorcycle riders and type of damage to motorcycle clothing during a crash have not been investigated since the study by Woods in 1996 from which the standards were developed [24].

Preliminary categorization of impact locations indicated that the results from this study were consistent with the European standard, with the majority of impacts occurring in zone 1 regions, and the least in zone 4. Abrasion and burst damage as well as contusions, abrasions and laceration injuries also followed this pattern. Burn injuries, cut damage and burst damage did not follow this pattern; however, the lack of an apparent pattern may be due to the small number of cases where this type of damage occurred.

Categorization of the impact locations into the OIC body regions demonstrated that the impact distribution differed slightly to that predicted by the principles of the European Standard. Body regions such as the forearms, lower leg and thigh suffered a large number of impacts. These regions are not zone 1 regions according to the European Standard; however, they experienced a similar number of impacts then some Zone 1regions.

The distribution diagram was used to observe which zone the impacts were occurring in for each body region. Impacts to the thigh occurred mostly to the zone 2 clothing region covering the thigh which already intends to protect riders from a high-risk of impact. However, 13 impacts still occurred to zone 3 covering the front of the thigh. This zone only protects a small body surface area and therefore this is a large number of impacts for the size of the area. Zone 2 could be extended to cover this area, eliminating the zone 3 region at this location.

The majority of impacts to the forearm occurred in zone 3, located at the anterior of the forearm. A large number of impacts were also seen to zone 3 upper arm, with 10 impacts to the anterior and six to the posterior of the upper arm in zone 3. Zone 2 could also be extended here to so that there would be no zone 3 region in the arm.

A large number of the impacts occurred to zone 4 of the lower leg with 8 impacts to the anterior and 7 impacts to the posterior of the lower leg. However, if appropriate motorcycle footwear was worn, this region of the lower leg would be covered by an additional layer of protection and no changes may need to be made to this area of the clothing.

The chest and abdomen experienced a larger number of impacts than the upper and lower back. The chest and abdomen are zone 4 regions, while the upper and lower back are zone 3 regions. It may therefore be justified to change the chest from a zone 4 to a zone 3 region.

These changes would greatly simplify the template for motorcycle clothing. However, it potentially decreases the number of zone 3 and 4 regions which may reduce the ability of manufacturers to provide ventilation and comfort in motorcycle clothing. This might have an overall detrimental effect as it could reduce the likelihood of motorcyclists wearing protective clothing in hot weather. Advances in materials technology might be able to address this issue by providing materials with high resistance to impact damage while still proving enough ventilation for rider comfort.

This study also investigated the different types of clothing damage seen to motorcycle suits following a crash. The most common forms of clothing damage were abrasion and tear damage, with little evidence of burst and cut damage. This suggests that tests for abrasion and tear resistance could be given a higher priority than burst or cut tests. It also indicates a need for research into abrasion and tear resistant materials and better understanding of which material properties effect abrasion and tear resistance.

Only a small amount of burst damage to the seams of clothing was observed in this study. Performance and manufacturing production methods of seams appear to have improved substantially over the years, as initially burst failure of clothing seams was the most common cause of garment failure [32].

Standards approved clothing is required to have multiple layers of stitching, including a layer which must be protected within the seams. None of the standard approved clothing in this study displayed any evidence of burst damage to the seams, and hence this multiple layer of stitching may be adequate to protect from burst damage. However, the sample of standards approved clothing in this study was small, so further examination of the performance of approved clothing in the real world is necessary.

An attempt was made to look at the effect of different road surfaces on the different types of clothing and the clothing abrasion sustained. However, the limited sample size of participants who crashed on unsealed roads (3/117) made any statistical analysis void. Additionally, road surfaces were only classified in terms of whether they were sealed or unsealed. Analysis of the effect of the road surface on the amount and severity of abrasion occurring would benefit from further characterisation of the road surfaces in terms of its roughness or coefficient of friction.

The absolute number of clothing items certified to the Standard observed in this study was very low. It was therefore impossible to draw any conclusions about the performance of standards approved

clothing versus clothing that was not approved to the Standard. It was also not possible to determine the level of performance of non-standards approved clothing i.e. whether or not it may have passed the Standard's tests. It was therefore not possible to investigate in this study whether the damage resistance requirements specified in the European Standard are appropriate or whether adjustments should be made. However it is worth noting that clothing designed for motorcycle use, regardless of certification or not, appeared to be effective in preventing skin injury as most skin injuries to protected skin occurred when the clothing was not specifically designed for motorcycle use. While earlier studies primarily looked at leather clothing, these findings support reports of the protective effect of motorcycle clothing even though most of the clothing in this study was made from other fabrics [6, 7, 21]. Moreover, clothing damage was seen predominantly among clothing designed for motorcycle use whereas skin injury without overlying clothing damage occurred mostly among clothing not designed for motorcycle use. This further indicates the protective effect of the specifically designed clothing.

A limitation to these results is the subjective nature of determining the exact location of where damage and injury locations occurred related to standardized clothing and body diagrams defining the zones used in the Standard. The accuracy of the distribution of impact locations by zones may have been affected by this subjectivity. Currently, there is no other method for determining accurate locations of clothing damage. Further work will investigate potential methods for increasing the accuracy such as using computer modelling from photographs taken of the clothing, or creating a grid over the clothing such as that commonly used in studying the distribution of impacts on helmets. This analysis did not examine the severity of the abrasion and tear resistance and what injuries occurred as a result of the different impacts and different damage types. Future research will aim to examine the link between different damage types and resulting injuries as well as how the severity of damage affects the injury outcome. Further research will also focus on whether current materials offer suitable abrasion and tear resistance and which material types offer the best protection.

CONCLUSION

This study provides a confirmation of the general principles of the European Standard for motorcycle protective clothing. However, some minor changes to the zones may still be of benefit to the protective effect of motorcycle clothing. The results also indicate that more research into material abrasion may be required as this is the most common form of damage seen to motorcycle clothing.

These findings have implications for regulatory and consumer assessment protocols for motorcycle protective clothing and are useful for the development of these protocols.

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