Motorcyclist facial impact prevalence from novel analysis of Road Accident In-Depth Studies data

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I. INTRODUCTION

Motorcyclists are especially susceptible to impacts and traumatic injury to the head, face and brain. Helmets are the primary means of protecting against these injuries. Despite standards testing helmet protection, facial impacts are minimally tested in existing standards and rating protocols, which is partly due to limited real-world data capturing impacts to the facial region. Previous work has focused on fatally injured cohorts or includes data from before 2000 [1-3]. This study aims to provide a comprehensive, contemporary analysis of real-world motorcyclists' collisions data, focusing on helmet impact locations and head, brain and facial injury outcomes.

II. METHODS

We analysed collisions involving 353 motorcyclists from Great Britain's Road Accident In-Depth Studies (RAIDS) collision database reported between 1st April 2013 and 31st March 2025. Motorcyclist outcome (fatal/serious/slight/uninjured) and face and brain injuries were classified using AIS-coded injury and a previously validated free-text search method classifying traumatic brain injury (TBI) using Mayo severity [4-5]. In addition to RAIDS helmet status and damage fields, we identified 127 motorcyclists whose primary and subsequent head impact locations were verified with helmet damage independently by two researchers using photographs (90%, 114/127) or written expert collision investigator assessments, as in literature [1]. Three quarters of motorcyclists wore full face helmets, 13% wore modular or flip-up helmets and 6% wore open face helmets. Helmet regions were adopted from COST327 [2] to allow comparison and create facial/non-facial regions, as shown in Figure 1. Free use of RAIDS was approved by the Department for Transport, which notably grants CAG/REC ethics approval to this project. Additional ethics approval was granted from Imperial's Research Governance Integrity Team.

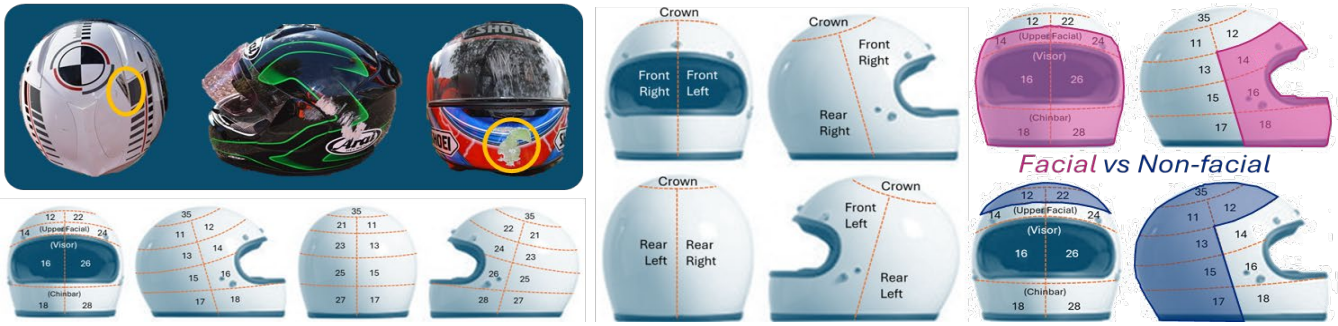

Figure 1 Head impact confirmed by helmet damage, grouped to identify facial and non-facial impacts.

III. INITIAL FINDINGS

We identified 353 motorcyclists (89.8% male, 88.7% aged 16-60 years, 93.5% injured) involved in collisions most commonly in urban speed limit zones (44.5% ≤30mph). Helmet use was high, with only 7 (2.0%) motorcyclists not wearing a helmet. Two thirds (67.4%, 238/353) of motorcyclists did not sustain a head, brain or facial injury. A quarter (24.9%) of motorcyclists sustained a traumatic brain injury (TBI), of which three quarters (75.6%) were moderate-severe according to the Mayo classification [6]. Over half (56.4%, 66/117) of those with injury to the head, brain or face sustained facial injury, of which a quarter were fractures (25.8%, 17/66). Other key injury types that motorcyclists sustained were subarachnoid haemorrhage and focal injury, in which we include laceration, contusion, transection and intracerebral haemorrhage (both 31.6%, 37/117), skull fracture (26.5%, 31/117) of which 20 (64.5%, 20/31) sustained basilar skull fracture.

Considering all impacts, i.e. primary and subsequent, 127 motorcyclist helmets had damage to the rear left (25.9%), front left (24.7%), front right (21.0%), rear right (19.8%), crown (6.6%) and front NFS (not further specified, 2.1%). Over half (58.7%) of impacts were facial (visor: 22.4%, upper facial, 17.9%, chin bar (16.1%) and NFS (2.2%). Among the 127 motorcyclists with helmet damage confirmed head impact, 85 (66.9%) did not sustain any head, brain or facial injury, demonstrating the overall protectiveness of helmets. Among the 127 with confirmed head impact, 42 (33.1%) sustained a head, brain or facial injury, of which 59.5% (25/42) sustained moderate-severe TBI and 69.0% (29/42) sustained a facial injury. Excluding 12 whose helmets came off after the initial impact, 77 (67.0%, 77/115) did not sustain a head, brain or facial injury, reporting a similar proportion to the overall cohort (67.4%, 238/353) suggesting the sub-analysis cohort with researcher-confirmed helmet impact location is representative of the RAIDS cohort overall. For 127 helmets with known impact locations, distinct

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primary impacts were identified in 125 helmets (2 unknown) as shown in Table 1. Most primary impacts were to the frontal regions, with prevalence led by the front left region (25.2%) followed by the front right (24.4%) and then rear left (22.8%). The prevalence of rear right (14.2%) and crown primary impacts (5.5%) were substantially lower. Almost the same proportion of primary impacts were facial (50.4%) and non-facial (49.6%). Considering facial regions, visor was impacted most (18.1%) followed by upper facial and chinbar regions (11.8%). Figure 2 shows impact region and injury outcome.

Cohort	All riders %		Primary impact locations			
			Facial %		Non-facial %	
All motorcyclists	353	-	63	-	62	-
Uninjured	23	*6,5%*	2	*3.2%*	2	*3.2%*
Slight	86	*24.4%*	15	*23.8%*	11	*17.7%*
Serious	180	*51.0%*	18	*28.6%*	29	*46.8%*
Fatal	60	*17.0%*	7	*11.1%*	9	*14.5%*
No head/face/brain injury	238	*67.4%*	39	*61.9%*	45	*72.6%*
Head/face/brain injuries	115	*32.6%*	24	*38.1%*	17	*27.4%*
Facial Injuries	65	*18.4%*	17	*27.0%*	11	*17.7%*
Facial Fracture	17	*4.8%*	3	*4.8%*	2	*3.2%*
All TBI	88	*24.9%*	17	*27.0%*	13	*21.0%*
Symptomatic	5	*1.4%*	0	*0.0%*	0	*0.0%*
Mild	16	*4.5%*	1	*1.6%*	4	*6.5%*
Moderate Severe	67	*19.0%*	16	*25.4%*	9	*14.5%*
Skull Fracture	30	*8.5%*	11	*17.5%*	5	*8.1%*
Basilar Skull Fracture	19	*5.4%*	6	*9.5%*	3	*4.8%*
Subdural Haematoma	14	*4.0%*	6	*9.5%*	1	*1.6%*
Subarachnoid Haematoma	37	*10.5%*	11	*17.5%*	4	*6.5%*
Focal injury	37	*10.5%*	7	*11.1%*	6	*9.7%*
Axonal Injury	6	*1.7%*	0	*0.0%*	1	*1.6%*
Extradural Haematoma	2	*0.6%*	0	*0.0%*	1	*1.6%*
Loss of Consciousness	27	*7.6%*	2	*3.2%*	5	*8.1%*

Table 1 A summary of injury outcome by impact type.

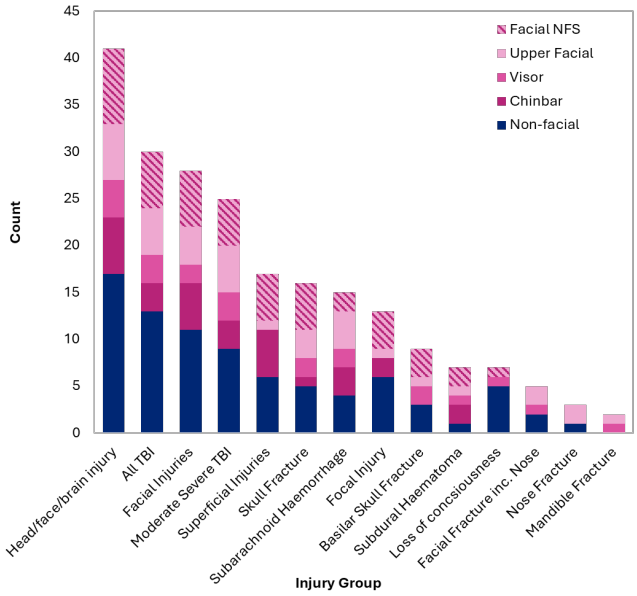

Figure 2 A count of injury outcomes by impact region.

IV. DISCUSSION

The deep analysis determined primary impact location for 125 motorcyclists in collisions from 2013-2025 and allowed us to report novel head impact injury association in a large, contemporary cohort. This much-needed contemporary data sample provides the field with a more complete picture of current motorcyclist injury since helmet and vehicle standards and technology has changed since literature reported cohorts. For instance, COST327 reported a 67% head injury rate which is substantially higher than our cohort 33% head, face and brain injury rate [χ^2=41.5, p<0.0001]. While this may in part may be explained by differences in collision severity in the cohorts, as helmets were worn in both cohorts, this may indicate helmet protection has improved since the 1990s.

Our novel analysis of contemporary motorcycle collisions showed that over half of the primary impacts to the helmet were in the face region, with visor sustaining the largest number of impacts followed jointly by the upper facial and chin bar regions, which is higher than Whyte *et al.*'s previously reported rate of 42.6% [1]. Our approach included a more representative cohort than previous work focused on fatalities alone, with the cohort of 127 motorcyclists with helmet analysis presenting with extremely similar injury prevalences to the overall cohort of 353, demonstrating the representative nature of the helmet analysis cohort. Compared to past literature, different injury distributions were observed including fewer basilar skull fractures, 7.2% in our confirmed head impact cohort vs 66.0% in Whyte *et al.*'s study of fatal motorcyclists, although a higher proportion in RAIDS were associated with primary facial impact (66.7% vs 41.9%) [1]. Future work should investigate non-primary injury in more detail to understand rider-to-vehicle and rider-to-ground head impact better and investigate whether RAIDS capturing more serious collisions has an influence on the head impact conclusions made. Additionally, increasing the sample size of comprehensively collected data will improve our ability to assess distinct injury pathologies.

Our study provides evidence for the exposure of the facial region of helmets in contemporary real-world collisions and which injuries to assess in a facial impact test. Facial protection is minimally assessed in helmet standards and we provide new evidence to improve helmet testing by including facial protection assessment.

V. REFERENCES

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