LOWER EXTREMITY RISK AND HARM ASSOCIATED WITH NARROW OFFSET FRONTAL IMPACT CRASHES

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ABSTRACT

While full frontal crash regulations have been associated with reductions in injury risk, research indicates that lower extremity injury risk remains high. The objective of this paper is to examine the nature and severity of lower extremity injuries and HARM resulting from narrow offset crashes. These crashes are of particular interest as frontal crash structures are often not effectively engaged by the collision partner and the subsequent intrusions can be high.

Analysis of an Australian real-world in-depth crash database found clear differences in injury severity between narrow offset, wide offset and full frontal crashes, with a logistic regression analysis adjusting for crash severity revealing significant differences in the likelihood of the occurrence of injuries, with offset frontal crashes being between 2.6 and 2.9 times more likely to sustain MAIS2+ injuries to the lower extremities than fully distributed impacts. Furthermore, wide offset crashes were 3.7 times more likely to result in a MAIS2+ injury to the upper portion of the lower extremities (femur and bony pelvis) and narrow offset crashes 2.5 times more likely to cause injuries of MAIS2+ to the lower portion of the lower extremities.

KEYWORDS: Frontal Impacts, Offset, Harm, Crashworthiness, In-depth Data

SINCE THE MID-1990s, and in parallel with the situation in the US and Europe, advances in the frontal crash performance of passenger vehicles on the Australian market were initially driven by new regulations, such as Australian Design Rules 69 and 73 for full and offset frontal crashes respectively. In more recent times, however, further improvements have been made in response to consumer demand spurred by new car crash testing programs like the Australian New Car Assessment Program (ANCAP). Much attention has been paid to the minimisation of head and chest injuries, with considerable success driven principally by the fitment of airbags (Fitzharris et al, 2006). It remains the case however, that injuries to the lower extremities are associated with considerable societal cost (Reid, et al, 2004) and should therefore remain a priority. The aim of this study was to use an Australian in-depth real-world crash dataset to conduct a detailed examination of the characteristics of MAIS2+ injury cases in three different frontal crash configurations, focusing on the incidence and severity of injuries to the lower extremities, with a view to understanding the injury mechanisms and providing a basis for countermeasure development.

METHOD

DATA SOURCE

In-depth data from the current Australian National Crash In-Depth Study (ANCIS), which commenced in 2000 at the Monash University Accident Research Centre, was used for this study. ANCIS enrols patients admitted to hospital as a consequence of a traffic crash. Ethical considerations demand that a case only proceed if the crash-involved occupant(s) (or a legally-binding alternative) and the vehicle owner (if different) consent to participate in the study.

Vehicle inspections were conducted in accordance with standard international practice (National Automotive Sampling System – NHTSA, 1989). Vehicle damage was coded as per SAE Recommended Practice J224b, with a Collision Deformation Classification (CDC) code assigned for each crashed vehicle. Delta-V and/or EBS were reconstructed using the computer program CRASH3 (Calspan Reproduction of Accident Speeds on the Highway Version 3).

Injuries sustained in the crash were transcribed from medical records at the treating hospital. Participants were also administered a semi-structured interview by a research nurse. All injuries, whether self-reported or medically verified, were coded according to the Abbreviated Injury Scale (AIS), 1990 revision (AAAM, 1998). The Injury Severity Score (ISS) was calculated for each case, acting as a global index of injury severity (AAAM, 1998). The ISS is derived from the AIS and ranges from 0-75, where the upper score represents an unsurvivable combination of injuries.

INCLUSION CRITERIA

The inclusion criteria for this study were as follows:

1. driver only;
2. driver age, gender, height and weight known. Fatalities were excluded from the analysis due to very few being present in the databases.
3. driver sustained at least one AIS1 injury with all injury data documented;
4. seat belt worn;
5. airbag status known;
6. light duty passenger vehicles, including passenger 4WDs (*aka* 'SUV's) and passenger vans ('MPV's), separated into small, medium and large categories;
7. frontal impact, with no rollover event in the collision sequence (see next section for more detailed definition);
8. known EBS (km/h);
9. known collision partner;

FRONTAL CRASH CONFIGURATION DEFINITIONS

Using the CDC, cases were initially selected where the principal direction of force was between 10 o'clock and 2 o'clock and third digit of the CDC was 'F'. The horizontal location of the direct contact damage (4th digit of the CDC, as shown in Figure 1 below) and the nature of the impact (6th CDC digit) were used to define frontal crash sub-types, these being:

FULLY DISTRIBUTED: fourth digit of the CDC was 'D' (distributed)

WIDE OFFSET: fourth digit of the CDC was Y or Z (left and centre/right and centre) and the sixth digit (nature of impact) was N (narrow), W (wide – direct damage wider than 410 mm), E (corner), or U (underrun);

NARROW OFFSET: fourth digit of the CDC was L or R (left/right) and the sixth digit (nature of impact) was N, W, E or U as above.

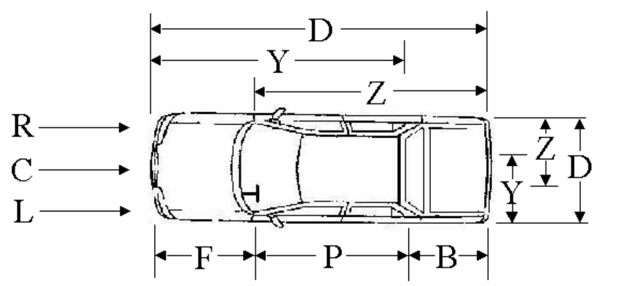

Figure 1. Fourth CDC digit, representing horizontal damage location.

COST OF INJURY – HARM

In addition to describing injuries using the AIS, the analysis reported here uses HARM as a means of costing injuries. HARM is a metric for quantifying societal injury costs from road trauma and involves a frequency and a unit cost component. The approach was pioneered by Malliaris, Hitchcock and Hedlund (1982). The HARM metric has been used in a number of Australian studies as a means of estimating the societal benefits arising from the introduction of new countermeasures (MUARC, 1992; Fildes, Digges, Dyte, Gantzer & Seyer, 1996), as well as a means for quantifying the financial benefits to society in evaluation studies (e.g. Fitzharris, Fildes, Newstead and Logan, 2006). Included within the HARM estimates are treatment, rehabilitation, loss of productivity and wages, pain and suffering allowances and administration costs. HARM values were originally based on the total societal crash costs originally published by Steadman and Bryan (1988), however HARM values have been re-factored by 2.5 to reflect more recent estimates of road crash costs published by the Australian Bureau of Transport Economics (BTE, 2000); notably, the proportional differences across body regions and severities remain the same.

In addition to the eight standard AIS body regions, a distinction was made between the upper and lower parts of the lower extremities in describing both the cost and risk of injury. The lower extremity was thus divided into the upper leg and associated bony structures (pelvis, femur, knee), referred to as 'LExt Upper'; and the lower leg (tibia, fibula, ankle and bones of the foot), referred to as 'LExt Lower'. The HARM analysis, however, utilised generic lower extremity values due to the unavailability of sub-region specific cost figures.

Use of HARM permits comparison of relative injury costs between fully distributed, wide and narrow offset frontal crash configurations, using the AIS body region and severity as a calculation basis. Table 1 shows the costs of injury by body region and AIS severity used. Note that, as of mid-July 2007, the Australian dollar bought approximately €0.63 or US$0.86.

Table 1. HARM injury costing.

Body Region	**Cost per injury (A$, '000)**						
	AIS 1	**AIS 2**	**AIS 3**	**AIS 4**	**AIS 5**	**AIS 6**	**U/K**
Head	5.25	24.50	100.75	232.25	820.50	830.75	3.75
Face	5.25	24.50	100.75	133.00	N/A	N/A	3.75
Neck	5.25	24.50	100.75	133.00	272.25	830.75	3.75
Chest	3.75	20.75	58.00	94.25	136.75	830.75	3.75
Abdomen-Pelvis	3.75	20.75	58.00	94.25	136.75	830.75	3.75
Spine	3.75	20.75	135.50	1167.50	1396.00	830.75	3.75
Upper Extremity	5.25	36.00	85.25	N/A	N/A	N/A	3.75
Lower Extremity	3.75	36.00	108.25	160.00	272.25	N/A	3.75

STATISTICAL ANALYSIS

A descriptive analysis of vehicle and driver characteristics is presented, split by frontal crash configuration. An analysis of vehicle and driver characteristics was undertaken to describe the sample and to explore potential differences between the fully distributed, wide and narrow offset frontal impact groups. To test for differences in sample group means ANOVA's were used with the Bonferroni correction applied for post-hoc comparisons (Keppel, 1991), while chi-square tests, the Kruskal-Wallis Test and the Mann-Whitney U-Test were used to test for differences in distributions between the groups (Siegel & Castellan, 1988).

Logistic regression was used to estimate the relative odds, or likelihood, of injury, while permitting the statistical control of differences in crash and occupant characteristics associated with drivers across the crash configurations (Hosmer & Lemeshow, 2000). In this analysis, the relative odds of drivers sustaining an AIS 2+ injury for each body region were compared between fully distributed frontal crashes, wide offset and narrow offset crashes. All injuries were verified by medical records and coded by AIS-trained coders.

Analyses were conducted using Stata Intercooled V8.2. A value of $p \leq 0.05$ was used to assess statistical significance. Institutional ethics committees approved all data collection activities and de-identified data was used.

RESULTS

Table 2 shows the demographic characteristics of study drivers by frontal crash configuration. Apart from the expected differences between males and females with regard to height and weight, occupant characteristics across the three crash configurations were well-matched.

Table 2. Demographic characteristics of drivers by frontal crash configuration

	Fully distributed (n=53)	**Narrow offset (n=31)**	**Wide offset (n=35)**	**Total (n=119)**
Number[1]				
Males	27	18	17	62
Females	26	13	18	57
Gender (% male)	50.9%	58.1%	48.6%	52.1%
Age[2]				
Mean (SD)	44.5 (15.8)	44.8 (15.7)	45.5 (18.2)	44.9 (16.4)
Range	18-87	18-76	18-85	18-87
Age: males				
Mean (SD)	42.6 (16.5)	41.2 (16.5)	48.1 (17.9)	43.7 (16.83)
Range	21-87	18-76	18-78	18-87
Age: females				
Mean (SD)	46.5 (15.2)	49.7 (13.7)	43.1 (18.5)	46.2 (15.9)
Range	18-71	24-75	20-85	18-85

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	Fully distributed (n=53)	Narrow offset (n=31)	Wide offset (n=35)	Total (n=119)
Weight[3]				
Mean (SD)	76.7 (17.6)	77.6 (13.7)	75.1 (18.2)	76.5 (16.7)
Range	35-120	42-98	45-122	35-122
Weight: males				
Mean (SD)	83.1 (16.3)	79.0 (13.8)	87.2 (15.2)	82.7 (15.3)
Range	60-120	42-98	63-122	42-122
Weight: females				
Mean (SD)	70.2 (16.7)	75.1 (13.9)	65.8 (14.7)	69.7 (15.6)
Range	35-100	48-90	45-100	35-100
Height[4]				
Mean (SD)	171.2 (10.3)	173.0 (10.6)	170.7 (10.0)	171.5 (10.3)
Range	149-200	151-193	152-188	149-200
Height: males				
Mean (SD)	178.5 (6.5)	177.6 (8.9)	178.7 (4.6)	178.3 (6.9)
Range	165-200	151-193	173-188	165-200
Height: females				
Mean (SD)	164.0 (8.1)	164.7 (8.4)	164.5 (8.5)	164.3 (8.1)
Range	149-180	151-175	152-178	149-180

Notes: [1]Gender $\chi^2(2)=0.6$, p=0.7; [2]Age – impact*sex F(2,113)=1.4, p=0.2; main effect sex – F(1,113)=0.6, p=0.4; main effect of direction, F(2, 113)=0.05, p=0.9; [3]Weight: – impact*sex, F(2,104)=2.2, p=0.1; **main effect sex – F(1,104)=16.5, p<0.001**; main effect of direction, F(2, 104)=0.008, p=0.9; [4]Height – impact*sex, F(2,104)=0.1, p=0.9; **main effect sex – F(1,104)=80.7, p<0.001**; main effect of direction, F(2, 104)=0.03, p=0.9

Table 3 demonstrates that there was no difference in the proportion of occupants across vehicle market class. There was a trend toward a larger number of cases in the Large + SUV grouping within the narrow offset configuration compared to wide offset crashes, with fewer occupants in the Small + Medium vehicle class. The median year of manufacture was the similar across the different configurations, with the range of years of manufacture broadly reflecting the study entry criterion of post-1989 vehicles. There was little difference in the collision partners across frontal crash configurations, although not unexpectedly, 60.4% of fully distributed crashes occurred with another vehicle, compared with 41.9% of narrow offset crashes and 42.9% of wide offset crashes respectively. Frontal airbag deployment was similar across configurations, with airbags fitted to approximately half the vehicles in the sample, 98% of which deployed during the crash. Examination of the location of primary impact relative to the driver in narrow offset crashes indicated the damage was on the driver's side of the vehicle two-thirds of the time, while the damage side was evenly split between driver and passenger in wide offset crashes.

Table 3. Collision characteristics by frontal crash configuration

	Fully distributed (n=53)		Narrow offset (n=31)		Wide offset (n=35)		Total (n=119)	
	N	%	N	%	N	%	N	%
Vehicle market class[1]								
SUV	1	1.9	1	3.2	1	2.9	3	2.5
Large	25	47.2	16	51.6	14	40.0	55	46.2
Medium	6	11.3	1	3.2	2	5.7	9	7.6
Small	21	39.6	13	41.9	18	51.4	52	43.7
Large + SUV	26	49.1	17	54.8	15	42.9	58	48.7
Small + Medium	27	50.9	14	45.2	20	57.1	61	51.3
Year of manufacture[2]								
Median	1997		1997		1996		1997	
Range	1989-2003		1992-2003		1992-2002		1989-2003	
Collision partner[3]								
Passenger car	20	37.7	9	29.0	8	22.9	37	31.1
SUV, Van	8	15.1	2	6.5	2	5.7	12	10.1
Pole / tree	6	11.3	11	35.5	9	25.7	26	21.8
Truck / bus	4	7.5	2	6.5	5	14.3	11	9.2
Roadside object	6	11.3	1	3.2	4	11.4	11	9.2
Other and unknown	9	17.0	6	19.4	7	20.0	22	18.5
Airbag[4]								
Not fitted	26	49.1	12	38.7	20	57.1	58	48.7
Fitted and deployed	27	50.9	18	58.1	15	42.9	60	50.4
Fitted, not deployed	Nil		1	3.2	Nil		1	0.8
Impact relative to driver[5]								
Fully distributed	53	100.0	N/A		N/A		53	44.5
Offset damage other side to driver	N/A		10	32.3	17	48.6	27	22.7
Offset damage driver side	N/A		21	67.7	18	51.4	39	33.6

Notes: [1]Vehicle market class collapsed into large + SUV vs. small + medium $\chi^2(2)=0.9$, p=0.6; [2]Year of manufacture $\chi^2_{kw}(2)=2.4$, p=0.3; [3] Collision partner $\chi^2(6)=7.1$, p=0.3; [4]Airbag not fitted vs. fitted and activated $\chi^2(2)=1.9$, p=0.4; [5]Impact relative to driver, tests not possible due to designed zero cell count.

Figure 2 shows the crash severity distribution for the cases, and while there appears to be little difference in the EBS distributions, the lack of cases prevents statistical significance testing. In contrast to the EBS distribution, the mean EBS across the three configurations differed ($F(2,116)=5.7$ ($p=0.004$). The mean EBS for fully distributed crashes was 53.7 km/h (SD=15.6), narrow offset crashes 45.4 km/h (SD=19.0) and wide offset crashes 42.8 km/h (SD=12.1). Post-hoc tests showed that this difference was driven by the difference in EBS between fully distributed and narrow offset crashes ($p=0.004$), while the mean EBS difference between fully distributed and wide offset crashes also approached statistical significance ($p=0.06$). The median EBS (fully distributed, 50.5 km/h; narrow, 45.0 km/h; wide, 42.0 km/h) was also significantly different between groups ($\chi^2_{kw}(2) = 11.7$, $p=0.003$), driven by differences between the fully distributed and offset groups (Mann-Whitney U-test, $z=3.3$, $p=0.01$). It remains important therefore that these differences be considered in the interpretation of the results.

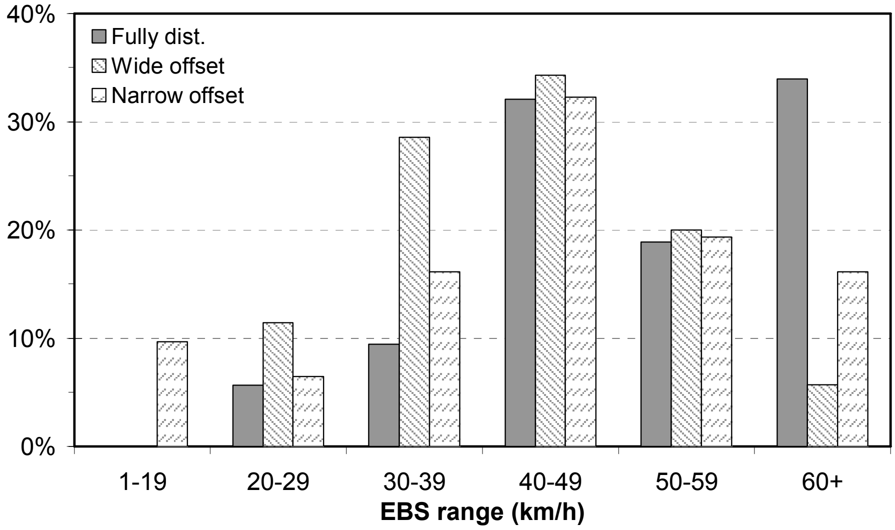

Figure 2. Crash severity distribution by frontal crash configuration.

Figure 3 presents the MAIS distribution across the three crash configurations, and the distributions appear well matched. The median ISS scores were similar across the crash types (fully dist.: 9; narrow: 10; wide: 10), with major trauma indicated by an ISS > 15 constituting 22.6%, 19.4% and 31.4% of cases respectively. There were no significant differences in median ISS between groups ($\chi^2_{kw}(2) = 0.6$, p=0.7), nor between cases of ISS 15+ ($\chi^2(2) = 1.4$, p=0.5). The similarities in injury severity between the crash configurations is partly likely to be a consequence of the study protocol and more specifically with the hospitalisation entry criterion, with crashes of lesser severity not being recruited into the data set, though it is important to be mindful of the abovementioned differences in crash severity.

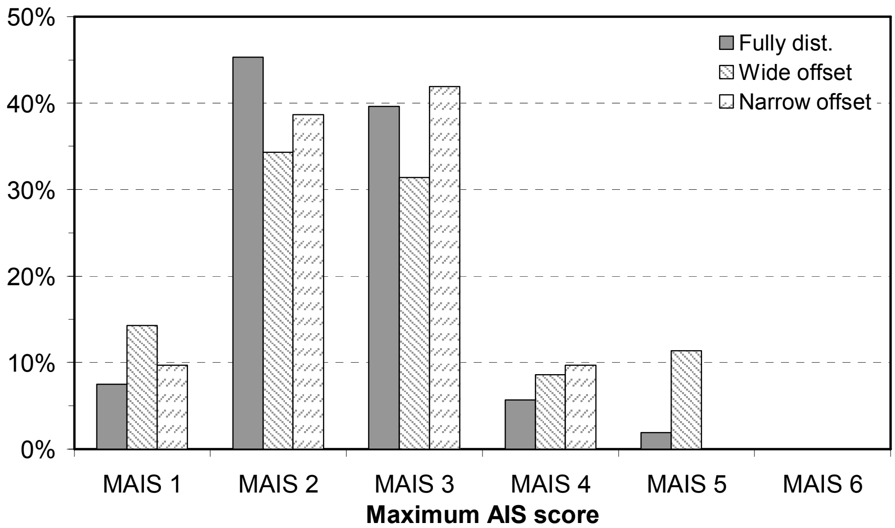

Figure 3. Maximum AIS by frontal crash configuration.

Table 4 presents the number and proportion of cases with MAIS 2+ injuries by configuration, while Table 5 presents odds ratios for the likelihood of MAIS 2+ injuries relative to fully distributed cases.

Examination of Table 4 and Table 5, showing the comparative analysis of MAIS2+ injuries, revealed several interesting differences across the frontal crash configurations. The sole confounding variable in the logistic regression was EBS, for each of the body regions. The likelihood of an MAIS2+ head injury was found to increase by 6% for every 1 km/h increase in EBS and this relationship was linear in the model; this represents the 'average' effect across the three configurations.

Similarly, the likelihood of abdomen/pelvis injuries increased by 5% per km/h, lower extremity and face injuries 4% per km/h and injuries to the upper extremity 3% per km/h.

Table 4 shows that the proportion of cases with MAIS 2+ head injuries did not differ across the configurations, but an apparent trend toward a higher incidence of facial injuries in wide offset crashes (23%) compared with fully distributed crashes (9.4%) was supported by the logistic regression analysis, which indicated the likelihood of MAIS2+ facial injuries was 5.2 times higher in wide offset crashes relative to fully distributed crashes; notably, the likelihood was lower, although not statistically, in narrow offset crashes relative to wide offset crashes.. These results are possibly explained by the larger amounts of rotation in wide offset frontal crashes, with drivers' heads consequently more likely to roll off the airbag and contact the A-pillar or own-side door and glazing. Wide offset crashes might also be more likely to arise from angled impacts than narrow offset impacts, yielding similar occupant kinematics. Similar behaviour would not be observed in narrow offset crashes, since lower levels of structural engagement are less likely to produce the necessary rotational torques. MAIS2+ injuries to the abdomen/pelvis were also higher in the wide offset group compared with the other two, with a corrected Odds Ratio of 3.9 for wide offset compared with fully distributed. There were no significant differences between the incidence or likelihood of MAIS2+ injuries to the chest, spine or upper extremities across the crash configurations.

For all lower extremity (LEx) injuries, MAIS2+ injuries were 2.6 times (CI: 0.94-7.0, p=0.07) more likely to occur in narrow offset crashes (and this approached statistical significance) and 2.9 times (CI: 1.1-7.8, p=0.03) more likely to occur in wide offset crashes relative to fully distributed crashes. There was no difference between the narrow and wide offset groups. In order to provide better discrimination within this body region, the LExt were split into two groups: LEx-Lower, consisting of the knee and below; and LExt-Upper, consisting of the femur and bony pelvis. Injuries to the upper leg region in wide offset cases (34%) were 3.7 times (CI: 1.2-11.0, p=0.02) more likely to occur than in fully distributed crashes. Furthermore, the OR of LExt-Upper injuries in narrow versus wide offset crashes was 0.28 (0.08-1.0, p=0.054), indicating greater risk in wide offset crashes. This appears consistent with impacts to the lower fascia causing injuries to the knees and, via the force transmission path through the femur, to the pelvic bones. No significant Odds Ratios were found for the LExt-Lower, however the narrow offset group was 2.5 times (0.9-7.2, p=0.09) more likely to experience such an injury than the fully distributed group.

Table 4. Distribution of MAIS2+ injuries by body region across the frontal crash configurations

	Fully distributed (n=53)		**Narrow offset (n=31)**		**Wide offset (n=35)**		**Total (n=119)**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Head	9	17.0	5	16.1	6	17.1	20	16.8
Face	5	9.4	4	12.9	8	22.9	17	14.3
Neck	Nil		1	3.2	1	2.9	2	1.7
Chest	24	45.3	10	32.3	16	45.7	50	42.0
Abdomen/Pelvis	6	11.3	3	9.7	7	20.0	16	13.4
Spine	12	22.6	5	16.1	6	17.1	23	19.3
Upper Extremity	19	35.8	10	32.3	10	28.6	39	32.8
Lower Extremity	17	32.1	14	45.2	16	45.7	47	39.5
Lower Ext. – upper	10	18.8	5	16.1	12	34.3	27	22.7
Lower Ext. – lower	13	24.5	11	35.5	10	28.6	34	28.6

Note: due to differences in EBS, logistic regression is required to determine odds ratios; refer Table 5.

Table 5. Odds Ratios for sustaining MAIS2+ injuries by body region for offset crashes relative to fully distributed crashes and narrow offset relative to wide offset crashes, adjusted for EBS.

	Fully distributed (referent)		**Narrow offset (n=31)**		**Wide offset (n=35)**		**Narrow vs wide (1, referent)**	
	OR	**CI**	**OR**	**CI**	**OR**	**CI**	**OR**	**CI**
Head[1]	1		1.37	0.37-5.1 p=0.5	2.08	0.57-7.6 p=0.6	0.66	0.16-2.7 p=0.6
Face[2]	1		1.95	0.45-8.3 p=0.4	**5.15**	**1.3-20 p=0.02**	0.37	0.09-1.5 p=0.2
Neck[3]	1		Not calculable – complete separation					
Chest[4]	1		0.52	0.20-1.4 p=0.2	0.90	0.36-2.2 p=0.8	0.58	0.21-1.6 p=0.3
Abdomen/Pelvis[5]	1		1.14	0.24-5.3 p=0.9	**3.89**	**0.99-15 p=0.05**	0.30	0.06-1.4 p=0.2
Spine[6]	1		0.57	0.17-1.9 p=0.4	0.60	0.19-1.9 p=0.4	0.95	0.26-3.5 p=0.9
Upper Extremity[7]	1		1.06	0.39-2.8 p=0.9	0.98	0.37-2.6 p=0.9	1.08	0.37-3.2 p=0.9
Lower Extremity[8]	1		2.56	0.94-7.0 p=0.07	**2.93**	**1.1-7.8 p=0.03**	0.86	0.31-2.4 p=0.8
Lower Ext. – upper[9]	1		1.08	0.31-3.7 p=0.9	**3.73**	**1.2-11 p=0.02**	0.28	0.08-1.0 p=0.054
Lower Ext. – lower[10]	1		2.51	0.87-7.2 p=0.09	2.09	0.72-6.1 p=0.2	1.19	0. 4-3.6 p=0.7

Notes: [1]**Head – EBS 1.06 (1.02-1.09, *p*=0.001)**; [2]**Face – EBS 1.04 (1.00-1.08, *p*=0.01)**; [3]Neck – EBS 0.95 (0.86-1.06, *p*=0.4); [4]Chest – EBS 0.98 (0.96-1.01, *p*=0.3); [5]**Abdo/Pelvis – EBS 1.05 (1.01-1.09, *p*=0.008)**; [6]Spine – EBS 0.98 (0.95-1.01, *p*=0.3); [7]**Upper Ex. – EBS 1.03 (1.00-1.05, *p*=0.03)**; [8]**Lower Ex. – EBS 1.04 (1.01-1.07, *p*=0.003)**; [9]**Lower Ex. Upper – EBS 1.04 (1.01-1.07, *p*=0.01)**; [10]**Lower Ex. Lower – EBS 1.04 (1.01-1.07, *p*=0.003)**.

Low amounts of data prevented an accurate analysis of contact sources, however as suggested by the results of the injury analysis however as can be observed in Table 6, the predominant injury source in narrow offset injuries was the footwell/toepan area, the major cause of LExt-Lower injuries. The right-side instrument panel (and below) comprised a large proportion of contacts in wide offset crashes, leading to the increased incidence of LExt-Upper injuries observed.

Table 6. Distribution of AIS2+ lower extremity injury contact sources by crash configuration.

	Fully distributed (n=17)		Narrow offset (n=14)		Wide offset (n=16)		Total (n=47)	
	N	%	N	%	N	%	N	%
C251, Floor including toe-pan	9	52.9	9	64.3	6	37.5	24	51.1
C12, Right side instrument panel	7	41.1	4	28.6	10	62.5	21	44.7
C252, Floor levers, controls	2	11.8	2	14.3	1	6.3	5	10.6
C10, Left side instrument panel, gear levers	3	17.6	Nil		Nil		3	6.4
C152, Belt-webbing, buckle	1	5.9	Nil		1	6.3	2	4.2
C4, Steering wheel	Nil		1	7.1	1	6.3	2	4.2
C101, Left side interior surface	Nil		1	7.1	Nil		1	2.1
C14, Knee bolster	Nil		Nil		1	6.3	1	2.1
C697, Unknown	Nil		Nil		1	6.3	1	2.1

Table 7 shows the mean HARM for each body region across the frontal crash configurations. It can be seen that the major source of HARM in fully distributed crashes was the lower extremities ($56,400, 33% of total mean HARM), with the upper extremities sustaining $32,800 (19%), chest 16% and head 12%. Mean HARM in wide offset crashes was 1.7 times higher, at $287,500 per occupant, with the head contributing $91,800 (32%) and the lower extremities $76,700 (27%), of which almost two-thirds was to the upper leg region. The chest was the other major source of HARM, at $41,700 per occupant (14.5%). HARM in narrow offset crashes was $167,000 per occupant, 36.5% of this to the lower extremities, evenly divided between upper and lower leg regions. Upper extremity HARM was $29,300 (17.5%) and Chest $27,200 (16%). Head HARM comprised only 4% in this crash type. Overall, the lower extremities were the source of 31% of HARM per occupant, compared with 18.4% for the head.

Table 7. Mean HARM ($A, ‘000) per occupant by frontal crash configuration.

	Fully distributed (n=53)	Narrow offset (n=31)	Wide offset (n=35)	Total (n=119)
Head	20.0	6.6	91.8	37.6
Face	10.9	9.8	15.8	12.1
Neck	0.6	1.8	3.5	1.8
Chest	27.1	27.2	41.7	31.5
Abdomen/Pelvis	11.4	14.9	13.9	13.1
Spine	10.9	16.2	15.6	13.7
Upper Extremity	32.8	29.3	28.6	30.7
Lower Extremity	56.4	61.2	76.7	63.6
Lower Ext. – upper	31.3	30.1	48.0	35.9
Lower Ext. – lower	25.0	31.1	28.7	27.7
All regions	170.2	167.0	287.5	203.9

CONCLUSION

This study used an Australian in-depth dataset of seriously-injured drivers in frontal crashes to investigate the incidence and severity of AIS2+ injury by body region in narrow offset (direct damage width less than 410 mm), wide offset and fully distributed crashes. A logistic regression analysis found that, for wide offset crashes compared with fully distributed crashes, statistically significant odds ratios of sustaining an MAIS2+ injury were 5.2 for facial injuries and 3.9 for injuries to the abdomen/pelvis region. Again, using fully distributed crashes as the referent, injuries to the lower extremities were found to be 2.6 times more likely in narrow offset crashes and 2.9 times more likely in wide offset crashes, with the latter statistically significant and the former approaching significance. To help further understand this trend, the lower extremities were sub-divided into upper (femur and bony pelvis) and lower portions (knee and below). Injuries to the LExt Upper were 3.7 times more likely in wide offset crashes (p=0.02) and trending toward 2.5 times more likely to the LExt. Lower in narrow offset crashes (p=0.09).

Mean societal HARM per crash was high for all crash types, comprising 33% of total mean HARM in fully distributed frontal crashes, 36.5% in narrow offset crashes and 27% in wide offset crashes, exceeded only by Head HARM (32%) in the latter crash type.

Despite the significant improvements realised in recent years to full and offset frontal crash performance, these results clearly show a need for further gains, particularly with regard to the lower extremities, with 31% of HARM (~A$64,000 per crash) associated with injuries to this body region.

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