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Prepared at the Request of Counsel

Wednesday, May 23, 2012

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Washington, D.C. 20005

Dear Scott:

Enclosed please find my report addressing the Pedestrian Research performed by JASIC (Japan Automobile Standards Internationalization Center). This report evaluates the appropriateness of the methodology and use of the available accident data used in the documents GTR9-2-07r1 pages 6-9 and GTR9-2-12 pages 2-6 and provides recommendations on how the available field data could be used to estimate the number of fatalities/injuries associated with tibia fractures.

Background

The Alliance of Automobile Manufacturers, through OICA, is participating in Phase 2 of UNECE Global Technical Regulation No. 9 on Pedestrian Impact Protection (GTR9). An Informal Group on Pedestrian Safety Phase 2 (IG PS2) has been established to further develop proposals to replace the EEVC/TRL Legform with the Flexible Pedestrian Legform Impactor (Flex-PLI) as the pedestrian protection lower leg measurement tool of GTR 9 and the ECE Regulation (ECE/TRANS/WP.29/1091, para.36).

A benefits analysis of the FlexPLI Legform vs. the TRL Legform was conducted by Japan Automobile Standards Internationalization Center (JASIC) (GTR9-2-07r1 and GTR9-2-12).

Alliance member companies support further developing Flex-PLI as a single harmonized test tool in order to enhance the safety level of lower leg pedestrian protection. The benefit should be assessed using biomechanics, biofidelity and testing criterion metrics.

Methodology

JP Research examined the data and methodology used by the JASIC group to determine the number of fatalities and injuries associated with tibia fractures.

In particular, the following factors were examined:

- The appropriateness and validity of the use of PCDS and NASS/CDS data to derive injury estimates by A.I.S. levels for pedestrians.

- The mixed use of various injury reference systems at the person and injury level (for example, the appropriateness of using MAIS 4-6 person-level injury data for pedestrians with tibia fractures which are typically AIS 2 or 3) and estimating fatalities for crash involved pedestrians with tibia fractures.

- The applicability of technical literature on probability of fatality/injury to develop fatality ratios for pedestrians.
    - For example, the estimation of cost reduction due to tibia fracture mitigation performed by JASIC used Figure 14 from "Accident Statistical Distributions from NASS CDS" (SAE International Technical Paper 2010-01-0139, Goertz A, Yaek J and Compton C, April 12, 2010) to calculate the probability of fatality by maximum known AIS.

- The application of historic motor vehicle occupant injury and fatality rates to develop projections of pedestrian injury risk, as well as the implied accuracy and precision of those projections.

- JASIC analyses combined several different data bases (FARS, PCDS and NASS CDS/GES) to derive the estimates of fatalities/injuries for tibia fracture. The data collection, sampling methods, representation, and validity of national projections by combining these data bases will be addressed to evaluate the accuracy and validity of conclusions on tibia fractures.

We do not address cost estimates and reduction in this report.

PCDS Data Analysis

The PCDS data is based on 6 major cities across the U.S. and includes vehicles which are predominantly model years 1990 through 1996. The 6 sites selected to participate in the PCDS are: Chicago, Illinois; Buffalo, New York; Fort Lauderdale, Florida; Dallas, Texas; Seattle, Washington and, San Antonio, Texas. The vehicle must be a late-model-year passenger car, light truck or van. Late-model-year was defined as being manufactured in the last 5 years of data collection. It also includes some non-late-model-year vehicles where the exterior design was the same as late model-year-vehicles (e.g. Ford Taurus 1988-1994). Due to the time period of data collection, over 60% of vehicles in PCDS are passenger cars, 10% are sport utility vehicles and 10-15% are pickups and vans. The PCDS data showed a higher proportion of fatalities associated with vans and pickups compared to cars. The U.S. vehicle fleet has changed significantly in the last decade. Over 40% of vehicle population are light trucks (SUVs, pickups and minivans) and the nature of pedestrian injuries by body region might be different from what was seen with a data set of primarily passenger cars. Given the vehicle mix that existed in the United States at the time PCDS data was collected, this is not a fair representation of the current U.S. fleet mix and consequently the use of PCDS data may not be a statistically valid representative sample of pedestrian crashes/fatalities/injuries in the U.S. today.

In addition, PCDS is not a large sample. JP Research repeated JASIC analyses based on the limited information available in the two GTR9 documents. There were only 404 pedestrians aged 16 years and older in the PCDS data set and only 24% (98) of the pedestrians sustained tibia fractures. This small size makes estimating fatalities/injuries for the whole nation with high confidence difficult. A standard 95% statistical confidence interval around this 24% estimate is 20% to 28%[1], which is fairly wide and should be included in any analysis which uses tibia fraction data from this PCDS file. JASIC did not account for this uncertainty in their estimates.

The PCDS uses data from 6 cities and the sampling is uneven over these cities[2]. In fact, in one city (Ft Lauderdale, FL) only one individual with a tibia fracture was found. 73% of all pedestrians with tibia fractures came from just three of the sampled cities, with remaining 26% coming from two cities (Chicago and Dallas) as seen in Appendix A, Table A. The sparse data on tibia fractures in PCDS, coupled with three cities in the entire U.S. accounting for 73% of the data sample makes for a poor sample from which to make projections.

The PCDS data identifies tibia fractures by AIS90 code[3]. (Appendix B). There are 98 pedestrians (16+ ages) with 147 tibia fractures in PCDS. Table 1a shows the breakdown of MAIS by tibia fracture for ages 16 or older.

[1] A 95% confidence interval shows the expected value of the estimate in repeated samples.
[2] Counts: Buffalo=21; Ft. Lauderdale =1; Dallas=15; Chicago=10; Seattle=28; and San Antonio=23.
[3] AIS90 codes for tibia fracture are 853404, 853406, 853408, 853410, 853412, 853414, 853416, 853418, 853420, and 853422.

Table 1a. Injury Severity With and Without Tibia Fracture
(Ages 16 or older)

MAIS	**Pedestrians With Tibia Fracture**	**Pedestrians With Tibia Fracture *Non-Fatal***	**Pedestrians With Tibia Fracture *Fatalities***	**Pedestrians No Tibia Fracture**	**Pedestrians No Tibia Fracture *Non-Fatal***	**Pedestrians No Tibia Fracture *Fatalities***
1	0	0	0	165	165	0
2	15	14	1	59	56	3
3	44	42	2	25	21	4
4	9	6	3	20	14	6
5	24	13	11	25	8	17
6	6	0	6	12	0	12
Total	98	75	23	306	264	42

Table 1a shows there were 65 fatalities, 42 without tibia fracture and 23 with tibia fracture. As Table 1a shows, 23% (23/98) of all pedestrians with tibia fracture were fatalities while 14% (42/306) of all pedestrians without tibia fractures were fatalities. Many of the fatalities with tibia fractures also had multiple injuries (head/neck/spine, etc.) which are discussed in detail in the subsequent sections.

Table 1b. Injury Severity With and Without Tibia Fracture
(Ages 16 or older; <= 40 KPH)

MAIS	**Pedestrians With Tibia Fracture**	**Pedestrians With Tibia Fracture *Non-Fatal***	**Pedestrians With Tibia Fracture *Fatalities***	**Pedestrians No Tibia Fracture**	**Pedestrians No Tibia Fracture *Non-Fatal***	**Pedestrians No Tibia Fracture *Fatalities***
1	0	0	0	137	137	0
2	8	8	0	42	41	1
3	27	25	2	17	16	1
4	1	1	0	8	7	1
5	1	1	0	10	3	7
6	0	0	0	2	0	2
Total	37	35	2	216	204	12

Note that there are 47 records with missing impact speeds for pedestrians without tibia fracture and 18 records missing for pedestrians with tibia fractures.

Table 1c. Injury Severity With and Without Tibia Fracture
(Ages 16 or older; > 40 KPH)

MAIS	Pedestrians With Tibia Fracture	Pedestrians With Tibia Fracture *Non-Fatal*	Pedestrians With Tibia Fracture *Fatalities*	Pedestrians No Tibia Fracture	Pedestrians No Tibia Fracture *Non-Fatal*	Pedestrians No Tibia Fracture *Fatalities*
1	0	0	0	5	5	0
2	4	3	1	8	7	1
3	10	10	0	5	3	2
4	7	4	3	10	5	5
5	17	10	7	8	3	5
6	5	0	5	7	0	7
Total	43	27	16	43	23	20

Note that there are 47 records with missing impact speeds for pedestrians without tibia fracture and 18 records missing for pedestrians with tibia fractures.

Tables 1b and 1c are the same as Table 1a except broken out by impact speeds less than or equal to 40 KPH and greater than 40 KPH. Not that Tables 1b and 1c do not sum to Table 1a because there are 65 records with missing impact speeds.

Comparison of JASIC vs. JPR Analysis of PCDS Data

The table presented by JASIC for the number of pedestrians sustaining tibia fracture by MAIS (slide 8- GTr9-1-07r1) significantly differs from our analysis of the PCDS data using the same criteria (Age 16+ and pedestrians with tibia fractures). Our data shows that there were 38 more pedestrians with tibia fractures (mostly with MAIS 2 and 3) as seen in our Table 1. We were not able to replicate the JASIC numbers for tibia fractures or non tibia fractures they presented in their table. However, their totals (tibia + non tibia) agree well with our total number of cases from the PCDS data. This could imply that there could be an error on their part in separating the data on tibia and non tibia fracture injuries in the PCDS data.

As Table 1 shows, there were 23 fatalities for tibia fractures in the PCDS data. Of the 23, only 3 had tibia fracture injuries (2 MAIS 3 and 1 MAIS 2) that were the most severe. JASIC could have estimated the percentage of pedestrian fatalities by using this PCDS data alone. They would have obtained 5% (3/65) instead of 32.7% they used.

It appears JASIC computed the percent fatality with tibia fracture as follows:

- For each MAIS level, they calculated the expected value of tibia fractures based on the NASS-CDS fatality ratio and multiplying this by the number of PCDS pedestrians with tibia fractures. (Ex: For MAIS 5, it is 17*.476=8)

- They repeated the above procedure for all (total column) cases at each level of MAIS. (Ex: For MAIS 5, it is 49*.476= 23).
- They sum all the MAIS levels for tibia fractures (both numerator and denominator) and calculated the percentage by dividing the expected values of tibia fracture by the expected value of the total.

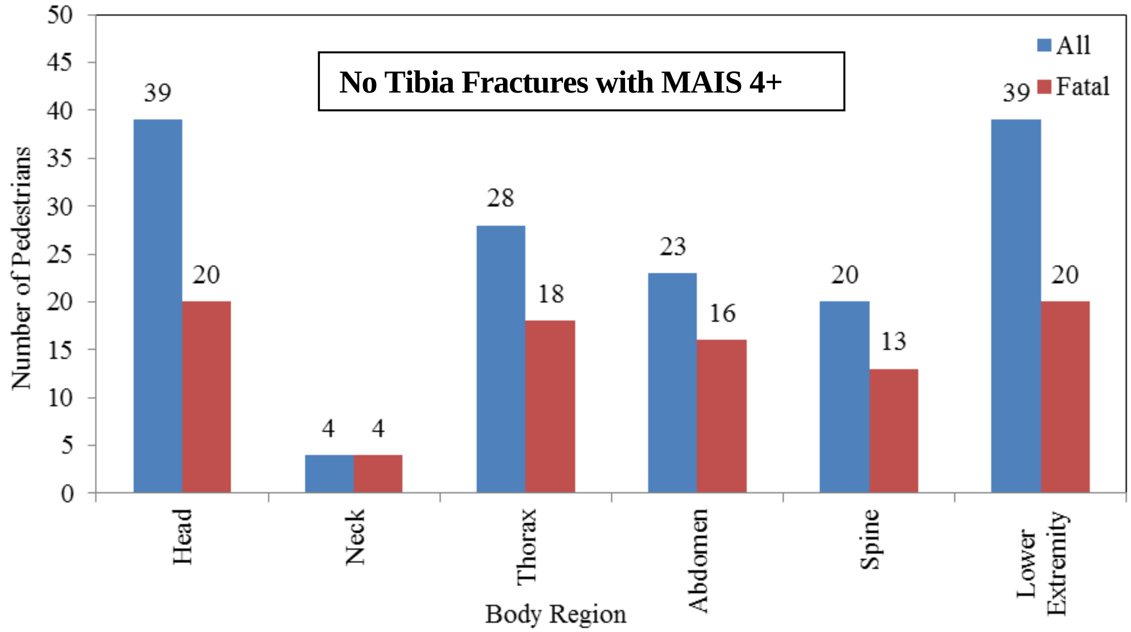
Since they might have miscalculated the number of tibia fractures and non tibia fractures, their remaining calculations are equally wrong.

In summary, we think their fatality estimates of tibia fractures are erroneous.

Tibia Fractures with Multiple Injuries

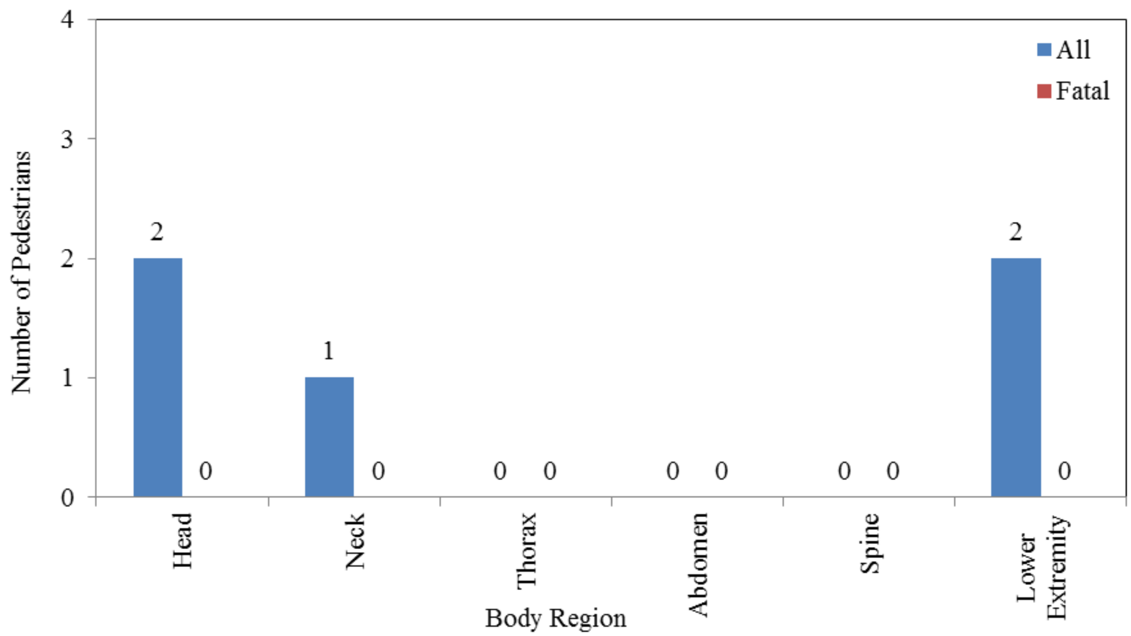
Tibia fractures should not be examined in isolation because those with tibia fractures often suffered from other injuries. Of the 98 who suffered a tibia fracture, just 2 had only that injury. It was far more common to suffer multiple injuries: In the PCDS data set, the median number of injuries coded for each pedestrian was 10; the maximum number sustained was 50. Some of these injuries were more severe than a tibia fracture which according to the injury classification manuals is AIS 2 or 3. There were 39 pedestrians out of the 98 with tibia fractures who also had more severe (MAIS 4 or greater) injuries. The body region associated with these injuries is shown in Figure 1a and the complete breakdown of all injury types by body region is presented in Appendix A, Table B. Figure 1a are for all impact speeds. All 39 pedestrians with tibia fractures who also suffered MAIS 4+ injuries had at least one MAIS 4+ head injury. Figure 1a also shows the breakdown by body region for pedestrian fatalities with tibia fractures. As seen in Figure 1a, 50% of pedestrians with head MAIS 4+ injuries (and tibia fractures) were also associated with a fatality. Consequently, using these injuries from PCDS data to project for national estimate of tibia fracture fatalities might have confounding factors (other serious injuries) that might overstate the tibia fracture caused fatalities.

Figure 1a. Injury Type by Body Region
(Pedestrians (ages 16+) with Tibia Fractures and Other MAIS 4+ Injuries)



There were 39 pedestrians with MAIS 4 or greater injuries.

Figure 1b. Injury Type by Body Region
(Pedestrians ages 16+ with Tibia Fractures and other MAIS 4+ Injuries and with Impact speeds <=40 KPH)

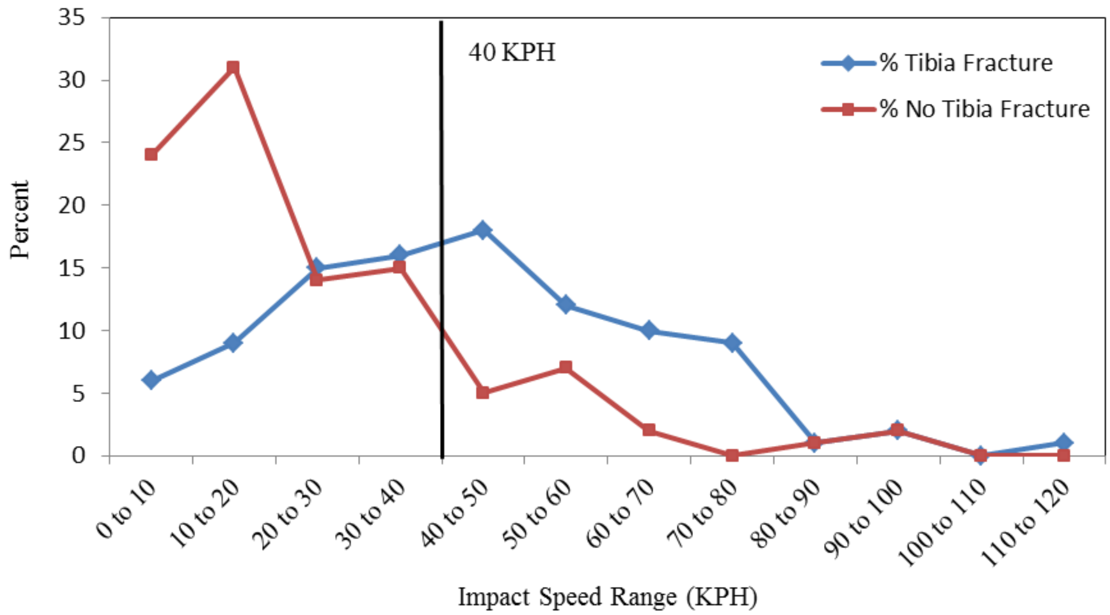


There were 2 pedestrians with MAIS 4 or greater injuries and impact speeds less than or equal to 40 KPH; there were also 18 records with missing impact speeds for pedestrians with tibia fractures.

Impact Speed

Impact speed is an important contributor to injury severity for pedestrians colliding with motor vehicles. We examined the PCDS data to identify the distribution of impact speeds for pedestrians with and without tibia fractures as shown in Figure 2. As seen in Figure 2, for those without tibia fractures, 17% had impact speeds greater than 40 KPH and for those with tibia fractures, 53% were associated with high impact speeds (>40KPH). The underlying data is presented in Appendix A, Table C.

Figure 2. Impact Speed Distribution

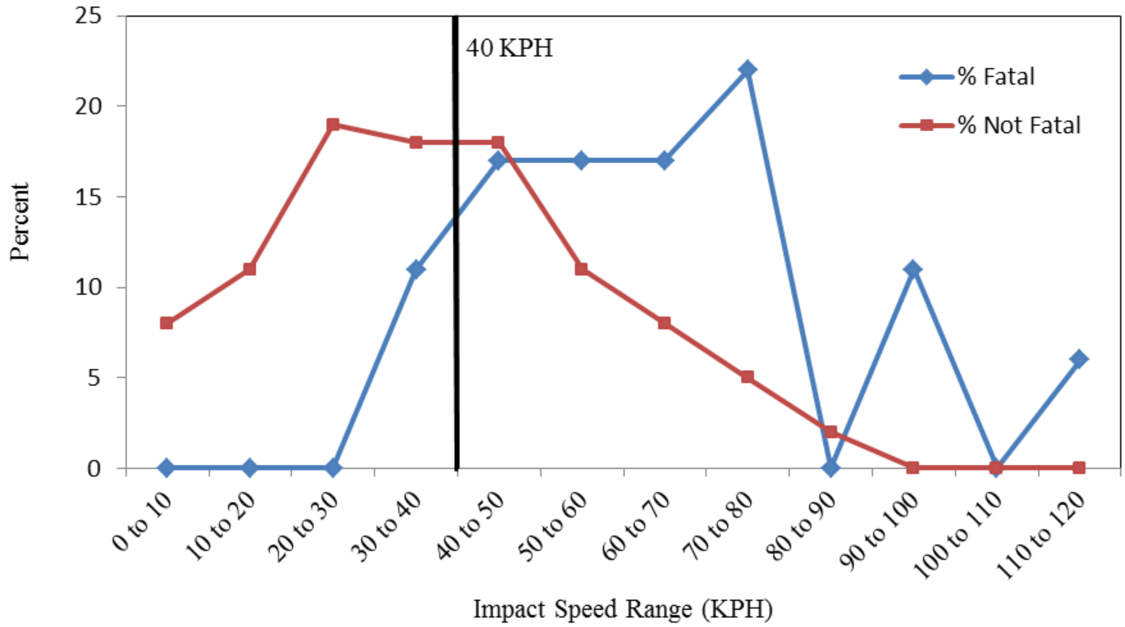


Counts for speeds are up to and including the right end points. E.g. "10 to 20" means speeds greater than 10 and up to and including 20 KPH.

Those with tibia fractures were on average involved in impacts with high speeds which implies there could be multiple injuries associated with these crashes, and as with fatalities, injury estimates cannot be reliably derived from this PCDS data to represent the injury experience of pedestrians with tibia fractures.

As expected, there was also a discernable difference in impact speed distribution between fatal and non fatal pedestrians. 90% of the fatal pedestrians with tibia fractures were involved in crashes with high impact speeds (>40KPH), while the corresponding percentage for non fatal pedestrians is only 44% as shown in Figure 3. Both Figures 2 and 3 also show sampling variability due to the small sample of the PCDS data.

Figure 3. Impact Speed Distribution for Pedestrians with Tibia Fractures



Counts for speeds are up to and including the right end points. E.g. "10 to 20" means speeds greater than 10 and up to and including 20 KPH.

The mixed use of various injury reference systems at the person and injury level (for example, use of MAIS 4-6 person-level injury data for pedestrians with tibia fractures that are typically AIS 2 or 3) and the high impact speed associated with fatalities, and the fewer cases for tibia fracture in their files, render JASIC's methodology of estimating fatalities/injuries for crash involved pedestrians with tibia fractures invalid.

Applicability of Technical Literature

The JASIC study relied in part on the SAE International Technical Paper 2010-01-0139, "Accident Statistical Distributions from NASS CDS", Goertz A, Yaek J and Compton C, April 12, 2010. In particular, JASIC used Figure 14 of the Goertz paper to estimate risk of pedestrian fatality. However, the Goertz study clearly states that this figure is based on vehicle occupants, *not* pedestrians. Quoting Goertz, "Figure 14 indicates that approximately 50% of occupants with maximum AIS level 5 injuries and approximately 1 in 5 occupants with maximum AIS level 4 injuries perish as a result of the accident."

Estimating the probability of fatality for occupants to represent pedestrian risk of fatality is not statistically valid. The differences are significant. The impact speeds, age group (drivers/pedestrians) and the nature of tibia fractures are significantly different between vehicle occupants and pedestrians colliding with a vehicle.

Combining Databases

The JASIC analysis combines several different data bases---FARS, PCDS, NASS-CDS, and GES---to derive the estimates of fatalities with and without tibia fractures. The data collection, sampling methods and representation of these data bases are substantially different and cannot be combined to make national projections for tibia fracture fatalities.

As mentioned in the PCDS codebook, "Unlike other NASS datasets the PCDS data is not a statistical sample and, therefore, there are no case weight variables." The sample is thus valid just at those locations where the data were collected. In particular, the PCDS cannot be used in direct combination with data sources which were based on stratified sampling plans which included the entire U.S., such as the NASS-CDS and GES data. By virtue of the design of data collection, the conclusions drawn from PCDS are only valid in the limited context of the 6 sites and the time frame of data collection. Extreme caution must be exercised in making general judgments from PCDS. Since the sampling variability of this data is unknown, the results are suspect and might be biased.

Proposed Methodology using FARS Data and Death Certificates Data

JASIC also used the FARS data to obtain fatality estimates for the nation. We agree that the FARS data contains records of pedestrian fatalities but it does not break the injuries down such that tibia fracture rates can be estimated. However, instead of combining different data bases to derive fatality estimates, we recommend one approach that might be subject to less uncertainty. The FARS records can be linked to U.S. death certificates records and with the cause of death with the ICD codes from death certificates and pedestrian fatalities from FARS, one can estimate the percentage of fatalities where the cause of death is a tibia fracture.

JP Research performed a preliminary study using 1999-2004 FARS and death certificates that are maintained in–house. A preliminary look at 18,000 FARS pedestrian records showed 72 cases with tibia fractures; most of these fatalities have injuries to multiple regions and the cause of death is head injury in a lot of these cases.

Conclusions

Based on the available data on JASIC study, the following conclusions were reached:

- The PCDS data is small sample and based on only 6 cities. Hence, deriving tibia fracture injury and fatality estimates using such small samples for the U.S. as a whole is not statistically valid and subject to uncertainty.
- JASIC's possibly erroneous method of estimating Tibia and non Tibia Fracture injuries and fatalities from the PCDS data leads to potentially misleading erroneous national projections.
- Using the NASS-CDS data on occupants to estimate pedestrian fatality ratios is invalid.

- Combining data sets that are census (FARS), stratified sample (GES) and tow-away crashes from a stratified sample (CDS) with a convenience sample (PCDS) is statistically invalid.
- One alternate approach to derive estimates of pedestrian tibia fracture fatalities involves using two census data bases (FARS) and (Death Certificates) and calculating the percentage of fatalities associated with tibia fractures.

The fact remains that estimating tibia fracture injury with the available databases is problematic.

Sincerely,

Jeya Padmanaban
President

Appendix A

Table A. Number of Cases by City in PCDS Data

City	Number of Cases
Buffalo, NY	21
Chicago, IL	10
Dallas, TX	15
Ft. Lauderdale & Hollywood, FL	1
San Antonio, TX	23
Seattle, WA	28

Table B. Injury Type by Body Region for 39 Pedestrians with MAIS 4+ Injuries

Body Region	Not Fatal	Fatal
Head	19	20
Face	12	17
Neck	0	4
Thorax	10	18
Abdomen	7	16
Spine	7	13
Upper Extremity	9	18
Lower Extremity	19	20

Table B2. Injury Type by Body Region for 39 Pedestrians with MAIS 4+ Injuries and Impact speeds <= 40 KPH

Body Region	Not Fatal	Fatal
Head	2	0
Face	1	0
Neck	0	0
Thorax	0	0
Abdomen	0	0
Spine	0	0
Upper Extremity	1	0
Lower Extremity	2	0

Note that there were 18 records with missing impact speeds for pedestrians with tibia fractures.

Table C. Impact Speed Distribution (KPH)

Impact Speed Range	**Number of Tibia Fractures**	**% of Tibia Fractures**	**Number of Non-Tibia Fractures**	**% of Non-Tibia Fractures**
0 to 10	5	6%	61	24%
10 to 20	7	9%	80	31%
20 to 30	12	15%	37	14%
30 to 40	13	16%	38	15%
40 to 50	14	18%	14	5%
50 to 60	10	12%	17	7%
60 to 70	8	10%	5	2%
70 to 80	7	9%	1	0%
80 to 90	1	1%	2	1%
90 to 100	2	2%	4	2%
100 to 110	0	0%	0	0%
110 to 120	1	1%	0	0%
Total	80	100%	259	100%

Table D. Impact Speed Distribution for Pedestrians with Tibia Fractures

Impact speed Range	Number of Fatalities	% Fatal	Number of Non-Fatalities	% Non-Fatal
0 to 10	0	0%	5	8%
10 to 20	0	0%	7	11%
20 to 30	0	0%	12	19%
30 to 40	2	11%	11	18%
40 to 50	3	17%	11	18%
50 to 60	3	17%	7	11%
60 to 70	3	17%	5	8%
70 to 80	4	22%	3	5%
80 to 90	0	0%	1	2%
90 to 100	2	11%	0	0%
100 to 110	0	0%	0	0%
110 to 120	1	6%	0	0%
Total	18	100%	62	100%

Appendix B

The following are pages 120-121 of the National Automotive Sampling System, 1993 Crashworthiness Data System Injury Coding Manual, produced by the National Highway Safety Administration, designating the Abbreviated Injury Scale (AIS) codes for tibia fracture.

CODE	ASPECT	INJURY DESCRIPTION
Patella		
852400.2	+	**Patella** fracture
852600.2	#	**Pelvis** fracture NFS, with or without dislocation, of any or one combination: acetabulum, ilium, ischium, coccyx, sacrum, pubis and/or pubic ramus [Enter one line of code per aspect. Simple closed fractures of superior and inferior right or left rami are not coded as comminuted fractures, but as closed fracture.]
852602.2		closed
852604.3		open/displaced/comminuted
852606.4	0	substantial deformation and displacement with associated vascular disruption or with major retroperitoneal hematoma NFS (crush)
852608.4		blood loss ≤ 20% by volume
852610.5		blood loss > 20% by volume
852800.3	6	**Sacroilium** fracture with or without dislocation
853000.3	5	**Symphysis pubis** separation (fracture)
853200.2	+	**Talus** fracture
853499.1	+	**Tibia*** NFS
853402.1		contusion
853404.2		fracture NFS
853406.2		condyles (plateau)
853408.3		open/displaced/comminuted
853410.2		intercondyloid spine
853412.2		medial malleolus
853414.2		open/displaced/comminuted
853416.2		posterior malleolus

* Tibia bone order: condyles, intercondyloid spine, shaft, malleoli.

CODE	ASPECT	INJURY DESCRIPTION
Tibia (continued)		
853418.3	+	open/displaced/comminuted
853420.2		shaft
853422.3		open/displaced/comminuted
853699.1	+	**Toe** NFS [Enter one line of code per lesion.]
853602.1		fracture
853604.2		amputation
853606.2		crush