PEDESTRIAN AND PEDALCYCLIST INJURY COSTS IN THE UNITED STATES BY AGE AND INJURY SEVERITY

Ted R. Miller, PhD
Eduard Zaloshnja, PhD
Bruce A. Lawrence, Ph.D.
Pacific Institute for Research & Evaluation
Calverton, Maryland

Jeff Crandall, PhD
Johan Ivarsson, PhD
University of Virginia
Charlottesville, Virginia

A. Eric Finkelstein, PhD
RTI International
Research Triangle Park, North Carolina

ABSTRACT

This paper estimates the incidence, unit costs, and annual costs of pedestrian and pedalcycle crash injuries in the United States. It includes medical care costs, household and wage work losses, and the value of pain, suffering, and lost quality of life. The estimates are broken down by body region and severity. They rely heavily on data from the health care system. Costs of pedestrian and pedalcycle injuries in 2000 will total $40 billion over the lifetimes of the injured. Most pedalcyclist injury costs and half of pedestrian injury costs do not involve motor vehicles. Youth ages 5-14 face greater annual risks when walking or driving their own pedaled vehicles than when being driven. Children under age 5 experience higher costs than their elders when injured as pedestrians. Our results suggest European and Japanese component tests used to design pedestrian injury counter-measures for motor vehicles are too narrow. Separate lower limb testing is needed for younger children. Testing for torso/vertebral column injury of adults also seems desirable.

Europe and Japan currently evaluate vehicle designs using tests on vehicle components. Europe has three testing organizations with separate test procedures: the European Enhanced Vehicle-Safety Committee (EEVC), the European New Car Assessment Program, and a voluntary agreement with vehicle manufacturers. Manufacturers are designing pedestrian injury countermeasures based on the component tests. The tests focus on several body regions (head, pelvis/proximal lower limb, and leg). For the head, impacts on both child and adult pedestrians are tested and equal weighting is given to each in terms of determining a score for the vehicle. For the other body regions, only the adult impact is tested.

The countermeasures are being developed based on injury frequency without examining basic data on severity that might dictate a focus on different occupant sizes or body regions. The young and elderly are over-represented in the pedestrian fatality statistics. More importantly, stature, and consequently age, has a strong influence on the child injury patterns (Woods et al. 2003). Data are needed to inform decisions about the age profile and priority body regions to use in future component testing.

This paper has two related objectives. First, it estimates the economic burden of pedestrian and pedalcyclist injuries in the United States and the extent of motor vehicle involvement by age group. These estimates support an assessment of how pedestrian and pedalcyclist injury severity vary by age group. Second, it provides total and unit costs to support interpretation of test results used to evaluate vehicle designs and other interventions aimed at reducing pedestrian and pedalcyclist injury. By providing finely differentiated costs, it facilitates vehicle design tradeoffs, for example, between bumpers and vehicle front-ends designed to be especially friendly to young pedestrians versus bicyclists versus elderly pedestrians.

Past analyses of pedestrian and pedalcycle injury costs typically were minor features of broader studies. Miller et al. (1999) included costs per mile bicycled in comparing safety across transport modes. Miller et al. (2000) considered these mechanisms in analyzing the leading causes of childhood injury costs. Miller et al. (1997), Wang et al. (1999), and Zaloshnja et al. (2004) all included non-occupant crashes in computing crash costs by crash type. Miller et al. (1998) estimated the costs of crashes involving alcohol-impaired non-occupants. Finally, Miller et al. (1994) and Miller and Levy (1998) computed costs of children's bicycle-related head and face injuries in performing benefit-cost analyses of child bicycle helmets.

This research report is the first to focus primarily on pedestrian and pedalcyclist (non-occupant) injury costs. With that narrow focus, we are able to examine the body region and severity distribution of non-occupant injury and its variation with victim age and motor vehicle involvement. Such attention is warranted since the non-occupant injury problem accounts for an estimated 14% of annual US highway crash costs (Miller et al. 1999).

Data scarcity proved a major challenge for this study. U.S. transportation data sets are inadequate to estimate incidence or describe the injuries accurately enough to cost them. Pedalcycle injury not involving motor vehicles or not on public roads (e.g., in driveways) is outside the scope of National Highway Traffic Safety

Administration (NHTSA) files. Moreover, although NHTSA's General Estimates System and Fatality Analysis Reporting System (FARS) estimate the number of non-occupant deaths and injuries involving motor vehicles on public roads, they do not routinely collect sufficient diagnostic detail on these non-occupant injuries to cost them. Thus, we could not analyze the details of non-occupant injury using established crash costing data and methods. Instead, we used a variety of health care data sets that included cause and diagnosis codes for injury incidents.

METHODS

We modeled total injury costs by multiplying the estimated incidence of injury times estimated unit costs of injury. Because we derived incidence from health care data bases, our estimates are differentiated between fatal injuries and non-fatal injuries by highest level of medical treatment (hospital admission, emergency department (ED) without admission, physician's office without admission or ED care, or hospital outpatient department only).

INCIDENCE AND SEVERITY ESTIMATION – We estimated the number and cost of pedalcyclist and pedestrian injuries, with and without motor vehicle involvement. For comparison purposes, we also made estimates for motor vehicle occupant injury.

Our incidence estimates are early results from a broader injury cost project. Fatal injury counts came from the 2000 National Vital Statistics System (NVSS) fatality census (National Center for Health Statistics – NCHS – 2004a), with supplemental information about on-the-road crash deaths from the FARS census of deaths involving motor vehicles on public roads. We used the 2000 Healthcare Cost and Utilization Project – Nationwide Inpatient Sample (HCUP-NIS) data file to estimate hospitalized nonfatal injury episodes. HCUP-2000 contains data on 8 million inpatient stays from 1,000 hospitals (Agency for Healthcare Research and Quality – AHRQ 2004a). We removed readmissions from the HCUP-NIS counts using readmission rates by primary diagnosis group derived from pooled 1997-1998 hospital discharge census data for Maryland, Vermont, and New Jersey – a choice driven by necessity; no other readily accessible data exist about readmission rates. HCUP-NIS identifies causes for 83% of injury incidents. Under the assumption that these cases were representative, we inferred missing external cause codes by applying the cause distribution by age group, gender, and primary diagnosis for cases with known cause.

We estimated injuries treated in the ED from the 1999-2000 National Hospital Ambulatory Medical Care Survey (NHAMCS), which surveys a representative sample of 500 EDs (NCHS 2004b). We estimated the number of injuries resulting in medical treatment without hospitalization or ED treatment from parallel provider surveys in the NHAMCS family, the 1999-2000 National Ambulatory Medical Care Survey (NAMCS) and the 1999-2000 NHAMCS hospital outpatient department sample (NCHS 2004b).

NHAMCS and NAMCS detail injury cause and diagnoses but count visits, not incidents. Thus, NAMCS might report three office visits that resulted from a single pedestrian injury. To estimate incident counts, we compared these data with data from data sets that counted incidents but had other faults that precluded their use as the primary incidence data sets. Excluding those who died or were hospitalized, we compared the NHAMCS ED visit counts to ED-treated injury incidence from the 2001 National Electronic Injury Surveillance System – All Injury Program (AIP, National Center for Injury Prevention and Control 2004). This nationally representative sample of newly injured patients treated in EDs does not code where non-occupant injuries occurred. The comparison revealed the AIP incidence and NHAMCS ED visit counts agree to within 2.5%, suggesting the NHAMCS ED counts are sound incidence estimates.

We compared the other visit counts with incidence and visit counts by broad cause from the 1999 Medical Expenditure Panel Survey (MEPS, AHRQ 2004b). MEPS tracks all health care for a national sample of non-institutionalized residents over a 2-year period but does not record whether motor vehicle injury victims were vehicle occupants. The comparison confirmed that the other data sets include many follow-up visits. We reduced the NHAMCS and NAMCS visit counts to match the MEPS victim counts within each age category (0-4, 5-14, 15-24, 25-44, 45-64, 65-74, 75+) and gender strata. We first removed NHAMCS and NAMCS cases within each strata where cause information was missing or coded as 'unspecified' (approximately 19% of cases from each file). Next, within the seven broad cause categories in MEPS (including motor vehicle), we multiplied the weights of all remaining visits within each strata times the ratio of the MEPS victim count to the NHAMCS or NAMCS visit count. This procedure reduced the weighted NHAMCS and NAMCS counts by age group, gender and broad cause so that they matched the corresponding MEPS incidence estimates. Depending on data set, causes are unspecified for 2%-5% of the NHAMCS/NAMCS cases and another 2%-6% involve motor vehicles but do not indicate if the patient was an occupant. Conservatively, we assumed none of these patients were pedestrians or pedalcyclists.

Abbreviated Injury Severity (AIS) scores (AAAM 1990) measure the threat to life resulting from an injury. The scores run from 0 (none) to 6 (unsurvivable). AIS scores and body regions were assigned using ICDmap-90 software (Johns Hopkins University & Tri-Analytics Inc. 1997). ICDmap-90 uses artificial intelligence and input from injury coding experts to translate ("map") International

Classification of Diseases, 9th Edition, Clinical Modification (ICD9-CM, NCHS 1990) diagnosis codes into AIS scores. For some injuries, this software is unable to determine the AIS level definitively from just an ICD-9-CM diagnosis code and gives a range of possible AIS scores instead. For any given diagnosis, we assumed that hospital-admitted cases, being the most severe cases, would have the highest AIS severity score in the range and the less severe non-admitted cases would have the lowest AIS score in the range. Once each of the patient's injuries was assigned an AIS score, we defined the injury with the highest AIS as the patient's primary diagnosis and assigned this injury's AIS score as the patient's Maximum AIS (MAIS) and its body region as the patient's body region. If two or more injuries had the highest AIS, we assigned the primary diagnosis as the first of these diagnoses listed in the discharge record.

The non-admitted cases are coded in ICD9 without the fifth digit of the clinical modification, which means they unavoidably are missing a body region identifier for some diagnoses, notably contusions and abrasions. These and a few other cases could not be AIS-scored; they were assigned scores of "9" denoting missing.

Diagnoses in mortality records are coded in the 10th Edition of the ICD (ICD10), not ICD9-CM. NCHS does not assign a primary injury diagnosis or require recording of a diagnosis on death certificates for injury (and none is entered for 36% of pedalcyclist and 53% of pedestrian deaths). ICDmap-90 cannot assign a body region to ICD10 data. NCHS supplied us with an unpublished mapping of ICD10 diagnoses to body regions (Lois Fingerhut, personal communication with Ted Miller, 2004) which we applied to the injury diagnoses. Following NCHS advice, we treated all diagnoses on the death certificate as contributing causes. To get an unduplicated death count by body region, we weighted each diagnosis by 1/n, where n is the number of diagnoses for the decedent. By convention, all deaths were assigned an AIS score of 6.

COST ESTIMATION – We estimated lifetime costs that result from a fatal or nonfatal injury. The costs fit into three categories: (1) medical, (2) work loss, and (3) quality of life. Following Gold et al. (1996), we discounted future costs to present value at a 3% discount rate and defined costs from a societal perspective that includes all costs – costs to victims, families, government, insurers, and taxpayers. Estimates were price-adjusted to 2000 dollars using the Employment Cost Index and Consumer Price Indices by medical care component (e.g., hospital).

MEDICAL COSTS – By diagnosis group, we used HCUP-NIS charge data adjusted with cost-to-charge ratios developed for use with HCUP-NIS by AHRQ, data from MEDSTAT's MarketScan database on the ratio of professional fee payments to hospital payments, inpatient rehabilitation cost estimates from Miller et al.

(2004), 1999 National Nursing Home Survey data on nursing home payments for patients who were discharged to nursing homes according to HCUP/NIS, and MEPS data (five interviews over a two-year period) about other post-discharge costs. Combining these estimates, we derived 18-month medical costs for injuries resulting in hospitalizations with live discharges. We used MEPS data to quantify 18-month unit medical costs for injuries not requiring a hospitalize-tion. To compute lifetime costs, we divided the estimates by the percentage of lifetime medical costs that occur in the first 18 months by diagnosis group and whether hospital-admitted. The lifetime percentages were computed from 1979-1988 National Council on Compensation Insurance Detailed Claims Information (DCI) data on more than 450,000 injury victims (Miller et al. 1995). More recent data on this percentage were not available. The DCI and MEPS showed similar percentages of costs in months 0-6 versus 7-18, which suggests the aged DCI percentages are reasonably accurate.

For fatalities, we obtained the distribution of place of injury death by cause and age group from 2000 NVSS data. We computed costs separately for six different places of death (death-on-scene, death-on-arrival to the hospital, death at the emergency department, death at the hospital after inpatient admission, death at home, and death at a nursing home). The medical costs incurred, depending on place of death, include coroner/medical examiner, emergency and/or non-emergency medical transport, emergency department treatment, inpatient hospitalization, and nursing home care.

WORK LOSS AND QUALITY OF LIFE LOSS – Work loss and quality-adjusted life year (QALY) loss per injury by diagnosis and age/gender adapt published estimates (Zaloshnja et al. 2001, Miller et al. 1998) by substituting a refined cost per day of household work lost from Haddix et al. (2003). As the original papers detail, the work loss days are built from 1993 Bureau of Labor Statistics data on days lost per injury with work loss; 1986-1992 National Health Interview Survey data on the probability an injury to an employed person will cause work loss; and DCI data on the percentage of injuries that result in permanent total and permanent partial disability, as well as the percentage of earning power lost for partial disabilities.

QALYs measure lost quality of life. The estimated QALY losses come from published sources (Miller 1993, Miller et al. 1995). They are based on expert judgment of typical functional losses to a specific injury over time plus the work loss data The functional and work losses are converted to QALY losses with survey-based values drawn from a systematic review of the literature (Miller et al. 1995).

Monetizing QALYs is controversial because it assumes that the monetary value per QALY is constant across the lifespan and that proportionate values for different health states are independent of income (e.g., that people of all income levels value the mobility loss from needing a walker at half the loss from needing a wheelchair). It also requires using a value of fatal risk reduction from one of several meta-analyses on the amount people routinely pay or are willing to pay in the expectation of saving one statistical life, but the meta-analyses disagree about this value. Following Zaloshnja et al. (2004), we monetize QALYs using the value of $3.4 million per statistical life (in 2000 dollars) from Miller (1990) that is incorporated into regulatory analyses throughout the US Department of Transportation.

The vehicle and highway design and regulatory analysis communities generally use monetized QALYs, while the public health community favors unmonetized QALY estimates for health service research applications. For compactness, we provide only Zaloshnja et al.'s (2001) monetized QALY estimates here. To obtain unmonetized QALYs, divide the monetized estimates by $98,851.

RESULTS

INCIDENCE – Table 1 shows that 6,106 pedestrians and 866 pedalcyclists were fatally injured in the United States in 2000, including motor vehicle crash victims and pedalcyclists and pedestrians who suffered fatal injury without motor vehicle involvement. An estimated 198,000 more pedestrian injury victims and 638,000 more pedalcyclist injury victims received medical treatment away from the scene annually in 1999-2000. Pedestrian injuries were more likely to be fatal or result in hospitalization than pedalcyclist injuries. Peak incidence rates for pedestrian injuries occur at ages 5-9, followed by 2-4 and 10-14. Although pedestrian injury incidence rates at ages 65 and over are lower than for other age groups except 0-1, the elderly have the highest fatal and hospitalized incidence rates. For pedalcyclist injuries, peak incidence is at ages 5-14, followed by 15-19.

COSTS – The estimated lifetime cost of pedestrian and pedalcyclist injuries in the US in 2000 is $40.4 billion (Table 2). To put the non-occupant injury problem in context, it costs 17.7% as much as motor vehicle occupant injuries. Pedalcyclist injuries account for 6.4% (1.6% + 4.8%) of the lifetime costs and pedestrian injuries for 11.4% (2.2% + 9.2%). In the 5-9 age group, the cost for pedestrian and pedalcyclist injuries ($5.0 billion) far exceeds the cost of motor vehicle occupant injuries ($3 billion). In the 10-14 age group the costs are similar – $5.0 billion and $4.9 billion, respectively. In both of these age groups, injuries to pedalcyclists not involved in motor vehicle crashes were the main culprit behind these high costs.

Table 3 breaks down the estimated costs by cost component and the patient's MAIS injury severity. The largest contributor to pedestrian and pedalcyclist injury costs (62.8%) is the $24.7 billion value of pain, suffering, and lost quality of life. Productivity -- wage and household work – losses are $12.1 billion (30.8%) and medical

Table 1. Annual incidence and rate of pedestrian and pedalcyclist injury by severity and age group, United States, 2000

Age	Fatal	Admitted	Non-admitted	Total	Rate/ 100,000 people
PEDESTRIANS INJURED					
0-1	102	275	119	495	7
2-4	191	1,279	9,071	10,542	93
5-9	230	2,712	23,808	26,750	135
10-14	207	2,312	15,075	17,595	88
15-19	346	2,587	7,708	10,642	54
20-49	2,707	12,456	82,609	97,772	81
50-64	997	3,991	24,429	29,417	71
65-74	522	2,011	1,629	4,161	12
75+	804	2,504	3,685	6,993	42
Total	6,106	30,128	168,133	204,367	70
%	3%	15%	82%	100%	
PEDALCYCLISTS INJURED					
0-1	-	93	2,013	2,106	28
2-4	5	620	16,988	17,612	156
5-9	66	3,378	165,772	169,216	855
10-14	125	4,765	159,037	163,927	823
15-19	68	2,749	73,080	75,896	381
20-49	356	8,720	170,146	179,221	148
50-64	138	2,884	6,814	9,836	24
65+	108	1,856	19,714	21,678	62
Total	866	25,063	613,563	639,492	219
%	0.1%	4%	96%	100%	

costs are $2.5 billion (6.4%). Fatalities account for half the costs, and MAIS-2 injuries for another quarter. Pedestrian-motor vehicle injuries have the highest cost per case ($135,558), followed by pedestrian-no motor vehicle ($96,098), pedalcycle motor-vehicle ($58,188), and pedalcycle-no motor vehicle ($17,831). The differences result in part from higher average MAIS. Incidents involving motor vehicles also cause a more costly mix of injuries within a MAIS level.

Table 4 shows costs for injuries with motor vehicle involvement by age group and MAIS. The variation in costs per fatality by age group in this (and other) tables primarily results from differences in expected remaining lifespan and work life. Fatality costs strongly influence the cost per victim across all injury severities. Overall, for example, costs average $153,503 per pedestrian killed or injured but just $47,280 per survivor (numbers not tabulated). For pedalcyclists, the comparable numbers are $64,425 and $32,300. Clearly, average MAIS is lower for pedalcyclists than for pedestrians at all ages. Elderly pedalcyclists have higher MAIS scores. Average MAIS varies modestly for other age groups. Average costs per victim (including both survivors and those who die) and per survivor are high at ages 0-4 and 15-19, as well as for pedalcyclists over age 64. Estimated mean costs per pedestrian-motor vehicle injury for adults ages 20-64 and ages 65 and over, however, are virtually identical.

Table 2. Total lifetime costs of pedestrian, pedalcyclist, and motor vehicle injuries (in millions of dollars) and their percentage contributions, by age group, United States, 2000

Age	Pedalcycle, Motor Vehicle	% of Row	Pedestrian, Motor Vehicle	% of Row	Motor Vehicle Occupant	% of Row	Pedalcycle, No Motor Vehicle	% of Row	Pedestrian, No Motor Vehicle	% of Row	Total	% of Row
0-1	4	0.2%	231	13.6%	1,178	69.3%	33	1.9%	255	15.0%	1,701	100%
2-4	41	0.9%	286	6.5%	2,815	63.6%	367	8.3%	917	20.7%	4,426	100%
5-9	425	5.0%	236	2.8%	3,469	40.9%	2,735	32.3%	1,613	19.0%	8,478	100%
10-14	752	7.6%	224	2.3%	4,865	49.4%	2,588	26.3%	1,425	14.5%	9,854	100%
15-19	431	1.2%	488	1.4%	31,402	89.0%	1,262	3.6%	1,689	4.8%	35,272	100%
20-49	1,585	1.2%	2,667	2.0%	116,664	86.4%	3,130	2.3%	10,962	8.1%	135,008	100%
50-64	292	1.4%	503	2.3%	17,518	81.4%	576	2.7%	2,638	12.3%	21,527	100%
65-74	61	0.9%	153	2.3%	5,562	83.0%	177	2.6%	747	11.1%	6,700	100%
75+	34	0.7%	113	2.5%	3,680	80.5%	98	2.1%	644	14.1%	4,569	100%
All	3,625	1.6%	4,901	2.2%	187,153	82.3%	10,966	4.8%	20,890	9.2%	227,535	100%

Table 3. Incidence, total lifetime costs and cost per case by cause of injury, cost category, and MAIS, 2000 dollars (total costs in millions)

MAIS	Cases	Medical cost	Lost productivity	Monetized QALYs	Comprehensive cost	Cost per Case
Pedestrian – Motor Vehicle						
1	84,835	127	220	32	378	$ 4,460
2	47,028	290	872	1,751	2,913	61,932
3	7,558	265	377	1,392	2,034	269,143
4	2,548	312	185	563	1,060	415,976
5	690	157	156	234	547	791,751
Fatal	4,821	53	4,490	9,246	13,789	2,860,162
9	6,022	17	62	9	88	14,618
All	153,503	1,221	6,360	13,227	20,809	135,558
Pedestrian – No Motor Vehicle						
1	36,112	35	50	8	93	$ 2,566
2	7,568	31	92	216	338	44,726
3	5,518	30	111	232	372	67,445
4	233	21	15	54	91	389,288
5	54	7	4	17	27	499,096
Fatal	1,285	7	1,333	2,620	3,960	3,081,647
9	94	1	5	1	7	74,806
All	50,864	132	1,610	3,146	4,888	96,098
Pedalcyclist – Motor Vehicle						
1	42,947	53	89	13	155	$ 3,612
2	2,837	46	50	362	458	161,339
3	1,434	46	27	317	390	272,263
4	789	64	15	196	275	348,061
5	189	31	21	70	122	643,720
Fatal	697	7	675	1,148	1,830	2,625,024
9	7,359	13	26	4	44	5,945
All	56,252	259	904	2,111	3,273	58,188
Pedalcyclist – No Motor Vehicle						
1	331,139	314	766	117	1,196	$ 3,611
2	209,971	359	1,748	4,239	6,346	30,222
3	4,020	67	206	993	1,266	314,935
4	1,650	82	131	424	637	385,975
5	330	26	24	107	157	476,779
Fatal	169	4	166	335	505	2,988,456
9	35,962	58	204	31	293	8,160
All	583,240	909	3,244	6,247	10,400	17,831
Total						
1	495,033	528	1,125	169	1,822	$ 3,681
2	267,404	726	2,761	6,567	10,054	37,600
3	18,530	408	720	2,934	4,063	219,256
4	5,220	480	346	1,236	2,062	395,035
5	1,264	220	204	429	853	674,856
Fatal	6,972	70	6,664	13,349	20,083	2,880,587
9	49,437	89	298	45	432	8,744
All	843,859	2,521	12,118	24,731	39,370	46,654
		6.4%	30.8%	62.8%	100.0%	

MAIS 9 = MAIS not codable from the diagnoses provided

Table 4. Incidence and lifetime cost of injuries to pedestrians and pedalcyclists caused by collision with motor vehicles in transport, by age and MAIS, in 2000 dollars (total costs in millions)

		Pedestrian – MVT			Pedalcyclist – MVT		
Age	MAIS	Cases	Cost per victim	Total cost	Cases	Cost per victim	Total cost
0-4	1	3,019	6,306	19	23	67,925	1.6
	2	691	305,666	211	54	402,644	22
	3	208	412,887	86	10	140,749	1
	4	133	525,019	70	17	404,780	7
	5	21	585,014	12	0	593,630	0.2
	Fatal	189	4,031,904	762	4	3,498,997	13
	9	60	83,693	5	3	101,629	0.3
	All	4,321	269,590	1,165	111	401,914	45
5-9	1	7,117	5,521	39	6,235	2,367	15
	2	3,279	145,440	477	368	349,642	129
	3	453	360,458	163	124	324,608	40
	4	187	475,075	89	90	454,264	41
	5	57	531,752	30	19	577,308	11
	Fatal	197	4,065,236	802	54	3,464,123	188
	9	75	113,113	8	12	102,334	1.3
	All	11,365	141,552	1,609	6,903	61,499	425
10-14	1	8,272	3,651	30	6,917	3,941	27
	2	5,398	61,488	332	455	241,541	110
	3	515	411,892	212	229	382,506	87
	4	198	471,506	93	187	446,196	83
	5	48	682,737	33	41	774,077	32
	Fatal	171	4,125,467	707	106	3,514,188	372
	9	2,690	7,504	20	7,220	5,577	40
	All	17,292	82,546	1,427	15,154	49,612	752
15-19	1	3,449	8,805	30	2,818	7,962	22
	2	2,599	76,440	199	346	221,805	77
	3	600	347,807	209	177	373,791	66
	4	214	505,591	108	118	442,625	52
	5	90	1,100,039	99	39	596,350	23
	Fatal	245	4,182,970	1,025	53	3,539,503	187
	9	88	102,422	9	20	127,385	2.6
	All	7,285	230,455	1,679	3,571	120,694	431
20-64	1	57,215	4,246	243	26,930	5,016	135
	2	33,534	46,991	1,576	1,477	166,595	246
	3	4,468	274,881	1,228	764	325,485	249
	4	1,436	434,681	624	330	418,753	138
	5	387	902,089	349	70	1,137,955	80
	Fatal	2,925	3,242,629	9,486	407	2,507,127	1,020
	9	3,019	13,962	42	85	108,557	9
	All	102,984	131,558	13,548	30,063	62,442	1,877
65+	1	5,763	2,892	17	23	13,687	0.3
	2	1,527	78,688	120	138	86,857	12
	3	1,315	110,692	146	130	140,126	18
	4	380	203,260	77	48	201,227	10

5	88	239,716	21	20	237,990	5
Fatal	1,093	921,919	1,008	73	673,952	49
9	91	21,518	2	18	33,522	0.6
All	10,256	135,563	1,390	450	210,897	95

MAIS 9 = MAIS not codable from the diagnoses available

Table 5 breaks down the pedalcyclist injury costs by age group, body region, and MAIS. Costs per patient vary dramatically, averaging $19,521 for pedalcyclists under 15 and $56,198 for older pedalcyclists. These differences are driven by costs, not incidence. Pedalcyclists ages 0-14 have lower average costs of MAIS 1 TBI, MAIS 2-5 TBI, and MAIS 2-5 other head/neck injuries ($5,558 vs. $10,431, $60,505 vs. $139,891, and $11,473 vs. $21,819) but higher average costs of MAIS 2-5 upper extremity and lower extremity injuries ($38,794 vs. $24,686 and $290,550 vs. $59,839). (Tables 5-7 do not sum to the totals in prior tables because they exclude estimates with small case counts.)

Tables 6 and 7 provide breakdowns similar to Table 5 for pedestrian injuries in motor vehicle crashes. Vertebral column injuries are rare under age 15 but an estimated 10% of injuries and 1.8% of injury costs at older ages. MAIS 2-5 and fatal torso injuries rank third in total costs behind TBI and lower extremity injuries; they account for 19% of costs of injuries with body region known (13% under age 15 and 20% above that). Estimated costs per patient do not differ greatly under and over age 15 ($126,985 vs. $137,945). Younger pedestrians experience many more MAIS 1 lower extremity injuries (34.5% vs. 13.6% of cases) and have higher costs per injury for MAIS 1 TBIs ($111,480 vs. $20,215), MAIS 1 and 2-5 other head/neck injuries ($36,882 and $127,828 vs. $12,622 and $29,239), and MAIS 2-5 lower extremity injuries ($322,830 ages 0-4 vs. $168,871 ages 5-14 vs. $105,650 ages 15 and over).

DISCUSSION

It is impossible to calculate the variance in our estimates, because we have no information about the uncertainty introduced by assumptions. Nevertheless, in comparing the estimates in our tables between categories, differences probably need to be fairly large to be statistically significant. Considering only variance due to injury mix and sampling error, Zaloshnja et al. (2004) estimate the variance of crash costs in much less homogeneous categories than the ones shown here, arriving at estimates equal to 10%-15% of the mean for crashes involving non-occupants providing there are at least 100 raw observations. Considering a broader range of contributors to the variance, Miller and Blincoe (1994) suggest it could be as much as 40% of the mean. Our conservative assumptions make it more likely that we underestimate than overestimate total costs.

Table 5. Total lifetime cost of injuries to pedalcyclists by age group, body region, MAIS, and cost category, in millions of 2000 dollars

Body region	MAIS	Cases	Medical cost	Lost productivity	Monetized QALYs	Comprehensive cost
			Ages 0-14			
Traumatic brain	1	8,292	12.9	28.7	4.5	46
	2-5	17,346	70.5	230.6	748.4	1,050
	Fatal	115	2.1	155.1	325.4	483
	9	5,035	8.2	23.6	3.7	36
Other head/neck	1	80,517	59.6	295.7	46.1	401
	2-6	9,282	9.4	53.1	60.6	123
	9	668	1.0	1.5	0.3	3
Spinal cord.	2-6	16	4.4	5.5	12.1	22
Vert. Col.	1	7,544	10.6	15.0	2.6	28
	2-6	38	0.3	5.4	7.9	14
Torso	1	5,244	5.5	11.8	1.8	19
	2-5	1,079	14.3	20.8	419.0	454
	Fatal	16	0.2	22.1	45.7	68
	9	4,512	5.8	20.8	3.3	30
Upper extremity	1	27,360	23.3	21.4	3.5	48
	2-5	71,444	96.8	690.3	1,984.4	2,772
Lower extremity	1	44,266	40.1	47.8	7.8	96
	2-6	2,282	29.2	120.9	514.6	665
Other/ unspecified	1	47,185	35.0	59.5	10.2	105
	Fatal	56	0.6	76.1	157.3	234
	9	20,248	34.8	131.4	20.7	187
TOTAL	All	352,853	464.6	2,039.4	4,384.0	6,888
			Ages 15 and over			
Traumatic brain	1	3,530	6.8	26.2	3.8	37
	2-5	8,714	162.8	280.7	775.6	1,219
	Fatal	277	4.6	295.7	528.2	829
	9	132	2.1	14.6	2.0	19
Other head/neck	1	30,276	26.5	84.8	12.0	123
	2-5	11,829	30.8	55.3	172.0	258
	Fatal	34	0.2	36.3	64.4	101
	9	34	0.5	2.5	0.3	3
Spinal cord.	2-5	145	34.1	42.4	91.1	168
	Fatal	8	0.2	7.6	14.6	22
	9	5	0.1	1.9	0.3	2
Vert. Col.	1	69	0.7	3.2	0.4	4
	2-6	471	8.5	30.0	16.8	55
Torso	1	17,714	22.2	91.9	12.9	127
	2-5	2,122	26.5	62.7	398.1	487
	Fatal	75	0.7	79.0	142.9	223
	9	130	0.8	2.2	0.3	3
Upper	1	45,822	66.4	104.5	14.5	185

	2-6	63,401	120.4	600.7	850.0	1,571
	1	32,915	35.3	52.7	7.5	96
Lower extremity	2-5	18,074	104.9	289.1	687.5	1,082
	Fatal	9	0.2	8.8	16.4	25
	9	1,486	2.2	5.4	0.7	8
	1	23,346	21.6	52.1	7.6	81
Other/ unspecified	2-5	14,690	8.1	10.3	19.8	38
	Fatal	252	2.0	259.9	478.6	741
	9	11,007	14.4	35.2	5.0	55
System wide	Fatal	9	0.1	11.4	20.0	32
	9	44	0.8	1.5	0.2	3
TOTAL	All	286,630	704.7	2,548.7	4,343.8	7,597

MAIS 9 = MAIS not codable from the diagnoses available. Total includes small cells that were not shown separately. Cells with less than 5 fatalities were combined with MAIS 2-5 cells into MAIS 2-6.

IMPLICATIONS – The numbers in Tables 5-7 are useful for countermeasure evaluation and interpretation of data from biomechanical testing. They also help to define problem size. For example, the frequent and severe upper and lower extremity injuries of young pedalcyclists relative to older ones merits investigation.

Bicycle helmets are effective against TBI and to a lesser extent, other head and face injury. Such injuries account for $1.6 billion in annual costs among the 0-14 year olds targeted by mandatory bicycle helmet usage laws and for $2.1 billion among those aged 15 and over who the laws do not cover. The higher costs per TBI or other head injury among bicyclists age 15 and over may result from greater bicycle helmet use at younger ages. These numbers need to be interpreted in the context of contemporaneous bicycle miles traveled and helmet usage rates by age group. A benefit-cost analysis of helmets for adults also seems desirable. Child pedestrians have much more costly MAIS 2-5 lower limb injuries than adults, suggesting the need for child-specific lower limb component testing. Our findings affirm the value of separate head injury testing for child pedestrians and of targeting the head and lower limb. Testing addressing adult torso/ vertebral column injury of adults also seems desirable. The very close match in estimated cost per pedestrian injury among older adults and other adults suggests that separate component testing to account for the higher prevalence of osteoporosis in the elderly is unnecessary.

Henary et al. (2003) found that child pedestrians hit by motor vehicles sustained less severe injuries than their adult counterparts. Their analysis focused on police-reported injury severity. With the substantially more accurate MAIS and cost scales, the story changes. MAIS 1 injuries are, indeed, more common among young children than adults, but the injury mix within AIS levels is quite different.

Table 6. Cost of injuries to pedestrians ages 0-14 in motor vehicle crashes, by body region, MAIS, and cost category, in millions of 2000 dollars

Body region	MAIS	Cases	Medical cost	Lost productivity	Monetized QALYs	Comprehensive cost
Traumatic brain	1	170	1.4	15.3	2.3	19.0
	2-5	1,298	76.9	107.2	407.9	592.0
	Fatal	267	3.2	312.5	773.5	1,089.2
	9	131	1.1	12.6	1.9	15.7
Other head/neck	1	833	3.9	23.2	3.6	30.7
	2-5	136	1.8	5.3	10.2	17.3
	Fatal	19	0.2	21.2	55.1	76.4
	9	7	0.0	0.7	0.1	0.8
Vert. Col.	1	11	0.1	0.6	0.1	0.8
	2-5	39	0.6	2.8	1.2	4.6
	Fatal	2	0.0	2.5	6.8	9.3
Torso	1	71	0.3	2.0	0.3	2.6
	2-5	571	11.6	19.7	172.2	203.5
	Fatal	53	0.5	61.3	152.6	214.4
	9	25	0.2	0.6	0.1	0.9
Upper extremity	1	4,329	3.5	3.4	0.5	7.4
	2-5	4,699	13.0	45.2	96.4	154.6
	Fatal	1	0.0	1.6	3.6	5.2
	9	644	0.9	1.5	0.2	2.6
Lower extremity	1	11,388	10.7	11.0	1.8	23.5
	2-5	4,434	54.9	140.8	625.9	821.7
	Fatal	3	0.1	3.9	9.2	13.2
	9	19	0.1	0.7	0.1	0.8
Other/ unspecified	1	1,607	2.5	2.2	0.3	5.0
	2-5	11	0.2	0.4	0.1	0.6
	Fatal	212	2.1	248.2	612.3	862.5
	9	1,997	3.3	8.4	1.3	13.0
TOTAL	All	32,976	193	1,055	2,940	4,187
Per Case	All		5,852	31,983	89,149	126,985

MAIS 9 = MAIS not codable from the diagnoses available.

Children under age 5 and ages 15-19 have higher costs per injury for MAIS 1 injuries, much higher costs for MAIS 2 injuries (with torso, upper extremity, and lower extremity injuries the reasons), and experience far more costly injuries overall.

LIMITATIONS – These estimates exclude many factors included in most motor vehicle crash costs (e.g., the costs in Zaloshnja et al. 2004, Miller, Lestina, and Spicer 1998, Miller 1993). Among them are mental health costs, legal and court costs, administrative costs of insurance claims processing, police and fire services costs, travel delay costs, and disruption costs to employers of the injured and their families.

Table 7. Cost of injuries to pedestrians ages 15 and over in motor vehicle crashes, by body region, MAIS, and cost category, in millions of 2000 dollars

Body region	MAIS	Cases	Medical cost	Lost productivity	Monetized QALYs	Comprehen-sive cost
Traumatic brain	1	1,527	4.4	23.2	3.2	30.9
	2-5	3,792	375.9	318.2	837.2	1,531.2
	Fatal	1,082	15.7	1,023.4	2,010.5	3,049.6
	9	154	2.4	15.3	2.1	19.9
Other head/neck	1	2,936	6.9	26.5	3.7	37.1
	2-5	1,932	8.0	17.5	30.9	56.5
	Fatal	116	0.8	111.7	221.8	334.4
	9	17	0.1	1.5	0.2	1.9
Spinal cord	1	5	0.2	1.8	0.2	2.2
	2-5	150	31.7	58.2	117.8	207.7
	Fatal	18	0.1	17.4	33.9	51.5
	9	12	0.4	4.4	0.6	5.4
Vertebral column	1	5,285	8.7	18.9	2.6	30.2
	2-5	6,650	18.8	49.4	27.0	95.2
	Fatal	31	0.2	30.2	57.8	88.2
Torso	1	2,153	4.7	12.9	1.8	19.4
	2-5	2,708	82.7	100.5	362.2	545.5
	Fatal	574	5.5	492.6	995.9	1,494.1
	9	143	1.3	3.4	0.5	5.1
Upper extremity	1	15,352	21.7	23.4	3.3	48.4
	2-5	13,634	48.1	152.3	242.0	442.4
	Fatal	7	0.1	4.0	9.9	14.0
	9	23	0.2	1.4	0.2	1.7
Lower extremity	1	16,451	27.3	28.7	4.1	60.1
	2-5	17,745	299.0	571.5	1,004.2	1,874.7
	Fatal	83	1.6	57.6	125.4	184.6
	9	1,799	3.6	9.3	1.4	14.2
Other/ unspecified	1	22,719	30.3	27.5	4.0	61.8
	2-5	26	0.3	1.5	1.0	2.8
	Fatal	2,324	22.3	2,073.8	4,122.6	6,218.7
	9	973	1.5	4.0	0.5	6.0
Systemic	Fatal	29	0.3	28.2	55.0	83.5
	9	75	2.8	1.6	2.5	6.9
TOTAL	All	120,525	1,028	5,312	10,286	16,626
Per Case	All		8,528	44,073	85,344	137,945

MAIS 9 = not codable from the diagnoses available.

The legal and administrative costs are the largest omission. NHTSA's General Estimates System data for 1998-2000 indicate that nationally 12.7% of pedestrian injuries and 8.9% of pedalcyclist injuries in motor vehicle crashes are hit and run. Medical costs, work loss, and even some quality of life loss typically will be compensated except in the hit and run cases, resulting in additional costs. Auto insurance claims processing will raise medical and work loss costs of compensated cases by 18.3% (with a maximum of $27,000, given the average policy limit of $148,000) and legal and court costs will raise them by another 25.1% (with a maximum of $185,700, given the average court award of $740,000 for catastrophic injuries) (Zaloshnja et al. 2001). For cases without motor vehicle involvement and hit and run cases, medical insurance claims processing will average 7.46% (Zaloshnja et al. 2001). In aggregate, then, legal and administrative costs would total an estimated $1.9 billion for pedestrian-motor vehicle injuries, $0.35 billion for pedalcycle-motor vehicle injuries, and a modest $0.08 billion for cases not involving motor vehicles.

Records on motor vehicle crash injuries treated in physician's offices often did not indicate if patients were drivers, passengers, or non-occupants. We assumed all were occupants. Allocating these patients in proportion to motor vehicle patients with details known would raise pedestrian and pedalcyclist injury costs by $0.3 billion.

The cost differences by age in this paper arise primarily because of differences in diagnosis mix (e.g., the percentage of injuries that are TBIs, the percentage of TBIs that are skull fractures versus concussions), place of treatment, expected lifespan, and current earnings. For any given diagnosis, the unit medical costs for injuries without hospitalization, the days of work-related disability while recuperating, and the percentage of lifetime quality of life lost to the injury did not vary by age.

The Medicare cost-to-charge ratios that we applied in computing hospital costs averaged 51.7% of charges. Payments probably exceed these costs, so we underestimate total payments by an unknown amount. Our knowledge of costs more than two years post-injury is dated, and almost nothing is known about costs more than eight years post-injury. The work loss estimates come from data on working age people so they may not apply well to youth and the elderly. The national adjustment for hospital readmission relied on readmission data from only three states. Data from a larger sample of states would be desirable, but no other large public-use files identify readmissions. Diagnoses indicating body region injured were missing for more than 40% of the fatalities.

CONCLUSION – Costs of pedestrian and pedalcycle injuries in 2000 will total $40 billion over the lifetimes of the injured. Our findings suggest that age makes a difference in the cost and nature of injuries that pedestrians and pedalcyclists experience in motor vehicle crashes. Torso/vertebral column injury of adult pedestrians is an important problem ignored in component testing.

The large majority of pedalcyclist injury costs and about half of pedestrian injury costs do not involve motor vehicles. Efforts to prevent these injuries should address the range of hazards associated with these pedestrian and bicycle modes, not just the interactions with the highway environment. The incidence and total costs of pedestrian and pedalcyclist injuries without motor vehicles involved would be even greater if we included assaults and rapes on paths and trails and over-exertion and thermal injuries associated with running, walking, and cycling.

Pedalcyclist and pedestrian injury incidence and cost are high. They place a large burden on society. Youth ages 5-14 face greater risks when walking or driving their own pedalcycles than when adults transport them. The riskiness of under-15 usage of non-motorized transport raises questions about letting this age group drive motorized, typically speedier vehicles including all-terrain vehicles, dirt bikes, dune buggies, and snowmobiles.

ACKNOWLEDGEMENT

Partial support for this research came from the National Center for Injury Prevention and Control (NCIPC), US Centers for Disease Control and Prevention, and from an auto manufacturer. Participating in the International Collaborative Effort on Injury Statistics, sponsored by NCHS with funding from the National Institute of Child Health and Development, also contributed critically to this research. Our thanks to Phaedra Corso, David Sleet, and Ann Dellinger of NCIPC for their very helpful comments on a draft. The paper represents the views of the authors but not necessarily of the funding agencies.

REFERENCES

AAAM. The Abbreviated Injury Scale 1990. Des Plaines IL: Association for the Advancement of Automotive Medicine, 1990.

AHRQ. NIS technical documentation, http://www.ahrq.gov/data/hcup/nis.htm, accessed June 2004a.

AHRQ. Medical expenditure panel survey, http://www.meps.ahrq.gov/, accessed June 2004b.

Gold MR, Siegel JE, Russell LB, Weinstein MC. Cost-effectiveness in health and medicine. New York, NY: Oxford University Press, 1996.

Henary BY, Crandall J, Bhalla K, et al. Child and adult pedestrian impact: The influence of vehicle type on injury severity. 47th Annual Proceedings, Association for the Advancement of Automotive Medicine, Barrington IL: AAAM, 105-126, 2003.

Haddix AC, Teutsch SM, Corso PS, ed. Prevention effectiveness, second edition. New York: Oxford University Press, 2003.

Johns Hopkins University, Tri-Analytics Inc. ICDMAP-90 Software User's Guide. Baltimore: Johns Hopkins, 1997.

Miller TR. The plausible range for the value of life: Red herrings among the mackerel. Journal of Forensic Economics, 3:3, 75-89, 1990

Miller TR. Costs and functional consequences of United States roadway crashes. Accident Analysis and Prevention 25(5):593–607,1993.

Miller TR, Blincoe LJ. Incidence and cost of alcohol-involved crashes in the United States. Accident Analysis and Prevention 26(5):583-592, 1994.

Miller TR, Douglass JB, Galbraith MS, Lestina DC, Pindus NM. (1994), Costs of head and neck injury and a benefit-cost analysis of bicycle helmets, in Head and Neck Injury, R. Levine, ed., P-276, Warrendale, PA: Society for Automotive Engineers, 211-240, 1994.

Miller TR, Langston EA, Lawrence BA, et al. Motorcycle injury rehabilitation cost, final report to National Highway Traffic Safety Administration, Calverton MD: PIRE, 2004.

Miller TR, Lawrence BA, Jensen A, Waehrer G, Spicer RS, Lestina DC, Cohen MA, Estimating the Cost to Society of Consumer Product Injuries: The Revised Injury Cost Model, Bethesda, MD: US Consumer Product Safety Commission, 1998.

Miller TR, Levy DT. Reducing highway crash costs: The cost-outcome analyses. In:von Holst H, Nygren A, Andersson A, eds. Transportation, Traffic Safety, and Health. Stockholm, Sweden: Karolinska Institute, 171–198, 1998.

Miller TR, Lestina DC, Galbraith MS, et al. United States passenger-vehicle crashes by crash geometry: Direct costs and other losses, Accident Analysis and Prevention, 29(3):343-352, 1997.

Miller TR, Lestina DC, Spicer RS. Highway crash costs in the United States by driver age, blood, alcohol level, victim age, and restraint use. Accident Analysis and Prevention 30(2):137–150; 1998.

Miller TR, Pindus NM, Douglass JB, et al. Databook on Nonfatal Injury: Incidence, Costs, and Consequences. The Urban Institute Press; 1995.

Miller TR, Romano EO, Spicer RS. The cost of childhood unintentional injuries and the value of prevention. The Future of Children 10(1):137-163, 2000.

Miller TR, Spicer RS, Lestina DC, Levy DT. Is it safest to travel by bicycle, car, or big truck? Journal of Crash Prevention and Injury Control 1(1):25–34, 1999.

NCHS. National Vital Statistics System home, http://www.cdc.gov/nchs/nvss.htm, accessed June 2004a.

NCHS. NAMCS/NHAMCS home. http://www.cdc.gov/nchs/about/major/ahcd/ahcd1.htm, accessed June 2004b.

NCHS. International Classification of Diseases, 9th revision: Clinical Modification. Hyattsville, Md. DHHS publication PHS 80-1260, 1980.

National Center for Injury Prevention and Control, Data sources for WISQARS Nonfatal, http://www.cdc.gov/ncipc/wisqars/nonfatal/datasources.htm, accessed June 2004.

Wang JS, Knipling RR, Blincoe LJ. The dimensions of motor vehicle crash risk. Journal of Transportation and Statistics, 2(1), 19-43, 1999.

Woods W, Sherwood C, Ivarsson J, et al. A review of pediatric pedestrian injuries at a Level 1 trauma center. Proceedings, 18th International Technical Conference on the Enhanced Safety of Vehicles, DOT HS 809 543, Washington DC: NHTSA, 2003.

Zaloshnja E, Miller TR, Council F, Persaud B. Comprehesive and human capital crash costs by maximum police-reported injury severity within selected crash types, 48th Annual Proceedings, Association for the Advancement of Automotive Medicine, Oak Park IL: AAAM, 2004.

Zaloshnja E, Miller TR, Romano EO, Spicer RS. HARM 2000: Crash Cost and Consequence Data for the New Millennium, 45th Annual Proceedings, Association for the Advancement of Automotive Medicine, Oak Park IL: AAAM, 159-186, 2001.