UCSF
UC San Francisco Previously Published Works

Title
Estimated total costs from non-fatal and fatal bicycle crashes in the USA: 1997–2013

Permalink
https://escholarship.org/uc/item/7988g6cz

Journal
Injury Prevention, 24(2)

ISSN
1353-8047

Authors
Gaither, Thomas W
Sanford, Thomas A
Awad, Mohannad A
et al.

Publication Date
2018-04-01

DOI
10.1136/injuryprev-2016-042281

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Downloaded from http://injuryprevention.bmj.com/ on August 29, 2017 - Published by group.bmj.com
IP Online First, published on June 1, 2017 as 10.1136/injuryprev-2016-042281

Estimated total costs from non-fatal and fatal bicycle crashes in the USA: 1997–2013

Thomas W Gaither,[1] Thomas A Sanford,[1] Mohannad A Awad,[1] E Charles Osterberg,[1] Gregory P Murphy,[1] Bruce A Lawrence,[2] Ted R Miller,[2,3] Benjamin N Breyer[1,4]

[1]Department of Urology, University of California, San Francisco, California, USA
[2]Pacific Institute for Research and Evaluation, Calverton, Maryland, USA
[3]Centre for Population Health Research, Curtin University, Perth, Australia
[4]Department of Biostatistics and Epidemiology, University of California, San Francisco, California, USA

Correspondence to
Dr Benjamin N Breyer, Department of Urology, University of California, San Francisco, Zuckerberg San Francisco General Hospital and Trauma Center, 1001 Potrero Ave Suite 3A20, San Francisco, CA 94110, USA; benjamin.breyer@ucsf.edu

Received 28 November 2016
Revised 27 February 2017
Accepted 29 March 2017

ABSTRACT

Introduction Emergency department visits and hospital admissions resulting from adult bicycle trauma have increased dramatically. Annual medical costs and work losses of these incidents last were estimated for 2005 and quality-of-life losses for 2000.

Methods We estimated costs associated with adult bicycle injuries in the USA using 1997–2013 non-fatal incidence data from the National Electronic Injury Surveillance System with cost estimates from the Consumer Product Safety Commission's Injury Cost Model, and 1999–2013 fatal incidence data from the National Vital Statistics System costed by similar methods.

Results Approximately 3.8 million non-fatal adult bicycle injuries were reported during the study period and 9839 deaths. In 2010 dollars, estimated adult bicycle injury costs totalled $24.4 billion in 2013. Estimated injury costs per mile bicycled fell from $2.85 in 2001 to $2.35 in 2009. From 1999 to 2013, total estimated costs were $209 billion due to non-fatal bicycle injuries and $28 billion due to fatal injuries. Inflation-free annual costs in the study period increased by 137% for non-fatal injuries and 23% for fatal injuries. The share of non-fatal costs associated with injuries to riders age 45 and older increased by 1.6% (95% CI 1.4% to 1.9%) annually. The proportion of costs due to incidents that occurred on a street or highway steadily increased by 0.8% (95% CI 0.4% to 1.3%) annually.

Conclusions Inflation-free costs per case associated with non-fatal bicycle injuries are increasing. The growth in costs is especially associated with rising ridership, riders 45 and older, and street/highway crashes.

INTRODUCTION

The health benefits of bicycling include increased physical activity and improved cardiovascular health.[1–3] Although these positive impacts are well documented, a growing body of literature suggests potential drawbacks to bicycling due to serious and sometimes life-threatening injuries.[4 5] Over the last 15 years in the USA, the incidence of hospital admissions due to bicycle crashes increased by 120%.[6] Given that costs resulting from a bicycle injury are 20-fold higher for hospital-admitted patients than for patients treated in the emergency department (ED) and released, an increase in the rate of admissions has major cost implications.[7]

Costs associated with bicycle injuries last were reported for 2005. Estimated medical and work loss costs due to fatal and non-fatal bicycle-related trauma exceeded $5 billion in the USA in 2005.[8] Estimated quality-of-life costs of bicycle injuries were $14.7 billion in 2000.[9] Another study estimated medical and work loss costs of bicycle-related brain injuries at $3.9–6.0 billion in 2002.[10] Motor vehicle involvement increases severity and associated costs of bicycle trauma.[9 11 12] Males and teens/young adults have disproportionately high bicycle-related trauma costs.[8] The only detailed analysis of bicycle injury costs by demographic characteristics of riders is from 2000.[9] Previous studies are limited by the use of only a year's worth of cost data. Calculation of costs over time, including non-fatal and fatal crashes, will provide a more comprehensive report of the societal burden of bicycle injuries.

We aim to estimate annual total costs (medical costs, work losses and quality-of-life losses) associated with non-fatal and fatal bicycle injuries of adults ages 18 and over in the USA over time. For non-fatal injuries, we use 1997–2013 incidence data from the National Electronic Injury Surveillance System (NEISS) and unit cost estimates from the US Consumer Product Safety Commission's Injury Cost Model (ICM). For fatal injuries, we use 1999–2013 incidence data from the Multiple Cause of Death (MCOD) data files, with unit costs primarily from the Web-based Injury Statistics Query and Reporting System (WISQARS). We seek to understand how rider demographics (age, sex) and location of the crash predict changes in total annual costs.

METHODS

Data sources

The NEISS database is a weighted national probability sample of consumer product-related injury visits to EDs in a sample of approximately 100 US hospitals. The NEISS database provides detailed information on consumer product-related injuries, including bicycles.[13] We queried the NEISS database for all bicycle-related injuries from 1997 to 2013 using NEISS product codes 5040 and 5033. This code choice excludes mopeds and cycles that do not have two wheels. Population projections of injuries were created using the NEISS complex survey design. We retained cases whose disposition after treatment was coded as released, transferred or admitted.

The MCOD file is maintained by the National Center for Health Statistics (NCHS). NCHS collects data from the 50 states, along with New York City and Washington, DC, which are responsible for registering deaths. It captures all deaths that occur in the USA.[14] Since 1999, the MCOD has used the International Statistical Classification of Diseases and Related Health Problems 10th Revision to classify and code causes of death.[15] We

To cite: Gaither TW, Sanford TA, Awad MA, et al. Inj Prev Published Online First: [please include Day Month Year] doi:10.1136/injuryprev-2016-042281

BMJ
Copyright Article author (or their employer) 2017. Produced by BMJ Publishing Group Ltd under licence.

Downloaded from http://injuryprevention.bmj.com/ on August 29, 2017 - Published by group.bmj.com

selected all cases where underlying cause of death was a pedal-cycle crash.

Miles bicycled in 2001 and 2009 from the National Household Travel Survey Data Extraction Tool (http://nhts.ornl.gov) served as exposure data.

Costs

For both fatal and non-fatal bicycle injuries, we estimated medical costs, work losses and quality-of-life losses per case. When these costs are added together, they represent a total cost to society. All costs are reported in inflation-free 2010 US dollars; effects of price inflation have been removed.

Non-fatal injuries

We estimated costs resulting from non-fatal bicycle injuries using the ICM.[16 17] Detailed documentation of the ICM can be found elsewhere[7] but a brief overview of each component is summarised here.

The ICM's medical and work loss costs are constructed using injury cases from two 2010 datasets of the Healthcare Cost and Utilization Project—the Nationwide Inpatient Sample (NIS) and the Nationwide Emergency Department Sample (NEDS). The Agency for Healthcare Research and Quality (AHRQ) receives the hospital inpatient and ED discharge data from participating states (45 in the NIS, 28 in the NEDS in 2010) and selects hospitals from these states whose discharges constitute representative 20% samples of US inpatient stays and ED visits. ICM developers analysed the cases from each dataset that represented injuries under the purview of Consumer Product Safety Commission (CPSC).

Medical costs for hospital-admitted injuries began with the hospital charge, which was multiplied by a facility-specific cost-to-charge ratio to obtain the cost of the initial visit. This was then multiplied by a series of factors to account for non-facility costs, readmissions and short and long-term follow-up costs. Where relevant, costs were added for rehabilitation and a nursing home stay. For injuries treated in the ED and released, cost of the initial ED visit, based on claims for outpatient services in the 2010–2011 MarketScan Commercial Claims and Encounters Database, was assigned by injury diagnosis. This was multiplied by factors representing short and long-term follow-up costs. For both hospital-admitted and ED-treated injuries, an emergency transport cost was added. Finally, claims processing cost was estimated as a percentage of the total, using a percentage specific to the expected payer.

The estimated cost of lost work included both short-term work loss and long-term disability. The diagnosis-specific expected number of days lost was multiplied by the average daily earnings and value of household production for a person of the victim's age and sex to arrive at short-term work loss. For permanent total disability, the present value of age-and-sex-specific lifetime earnings and household production were multiplied by the diagnosis-specific probability of permanent disability. For permanent partial disability, this was multiplied by an additional factor identifying the average extent of disability resulting from that type of injury. Costs in future years were discounted to present value using a 3% discount rate. Summing short-term, total disability and partial disability costs yielded total work loss.

Lost quality of life places a dollar value on the intangible results of injury. CPSC's ICM valued quality-of-life loss based on the amount juries awarded to injury victims for non-economic damages (losses excluding medical costs and work loss). It estimated that loss based on a log-linear regression with dependent variables including demographic, product-specific and injury-specific variables plus variables related to the legal case. Importantly, 18% of the awards analysed compensated bicycle or moped injury victims.[7] As jury awards for non-fatal injury are reasonably predictable, this method offers a practical approach to estimating quality of life lost that yields estimates consistent with approaches which measure quality-adjusted life years lost.[18 19]Although this method has critics,[20] CPSC chose it because it grounds CPSC regulatory analyses on quality-of-life losses actually paid in product liability lawsuits. US Department of Justice regulatory analyses also base their quality-of-life loss estimates on jury verdicts.[21]

NEISS diagnosis and body part codes were merged onto the NIS and NEDS cases. Mean medical, work loss and quality-of-life loss costs were then estimated by NEISS diagnosis and body part, age group (0–19, 20–54, 55–69, 70+) and sex. When necessary, dimensions were collapsed to obtain reasonable cell counts. The ICM cost estimates were then merged onto the NEISS data by diagnosis, body part, age group and sex.

Fatal injuries

Our estimation of medical costs and work loss for fatal injuries follows the methods of the WISQARS Cost of Injury Module.[22] We summarise the methods briefly here.

Medical costs depend on the place of death. A death at the scene of the crash incurs no medical cost. A death in a medical facility—ED, hospital, nursing home or hospice—incurs a cost that depends on the type of facility, the type of injury and the patient's age, plus the cost of emergency transport to the facility. In addition, all deaths incur a small coroner fee, and any death that results in an autopsy incurs an autopsy cost.

Lifetime productivity loss was estimated as the discounted sum of expected annual earnings over the victim's remaining potential working life. For a given year, expected earnings are the product of the sex-specific probability of surviving to the next year of age times sex-specific expected earnings for someone of that age. Parallel calculations valued lost household work.

WISQARS does not estimate or value quality-of-life loss. We used the average value of a year of life expectancy implicit in the jury verdict values for non-fatal quality-of-life loss.[18] We multiplied this dollar amount by the discounted age and sex-specific life expectancy of each victim. This procedure produces an estimate consistent with the non-fatal quality-of-life loss costs described above.

Statistical analysis

We used linear regression to estimate the average change in inflation-free costs by year. We performed linear regression of total costs by year, and then individually by medical costs, work loss and quality-of-life loss. We then stratified our analysis and performed linear regression on the proportion of total costs in three demographic groups: age (bicycle riders ≥45 years of age vs <45 years of age), sex (male vs female) and location of injury (street incidents vs incidents that did not occur on a street). All regression coefficients were considered statistically significant if $p<0.05$.

RESULTS

Non-fatal injuries

Total costs

Approximately, 3.8 million non-fatal adult bicycle injuries were reported during the study period (1997–2013). Total estimated costs due to non-fatal adult bicycle injuries during this time were approximately $227 billion in 2010 US dollars. The

Downloaded from http://injuryprevention.bmj.com/ on August 29, 2017 - Published by group.bmj.com

Table 1 Mean incidence, cost per case and total annual costs by year for non-fatal bicycle injuries, USA, 1997–2013

		Cost per case							Total costs
Year	Incidence	All adults ($)	Age 18–44 ($)	Age≥45 ($)	Female ($)	Male ($)	Street or highway ($)	Other location ($)	All adults ($)
1997	177 275	52 495	47 501	68 275	34 889	58 825	70 330	39 528	9306 033 664
1998	191 714	46 770	44 702	53 859	36 285	50 485	56 002	40 924	8965 732 182
1999	192 568	48 826	45 277	59 224	38 582	52 558	58 583	42 149	9402 329 754
2000	205 739	47 704	45 612	53 125	32 512	53 404	58 422	39 621	9814 180 593
2001	207 924	50 231	46 443	60 165	39 692	53 834	61 600	41 801	10 444 154 821
2002	194 063	51 783	44 921	68 023	43 239	54 846	61 634	42 997	10 049 167 552
2003	187 569	55 131	51 166	63 698	36 555	61 814	64 881	45 319	10 340 809 723
2004	193 338	56 433	48 098	72 658	38 278	62 856	66 975	43 193	10 910 739 636
2005	190 823	62 971	53 612	80 822	43 102	70 191	75 422	48 520	12 015 719 784
2006	205 260	64 411	56 533	77 717	41 757	72 643	77 606	48 604	13 221 061 102
2007	221 050	61 938	52 859	77 121	43 444	68 371	72 955	50 189	13 691 441 662
2008	239 511	62 339	55 182	73 757	38 357	71 527	73 832	50 133	14 930 961 469
2009	244 830	65 711	57 341	78 809	43 463	73 722	75 701	54 598	16 085 794 925
2010	257 796	68 523	58 423	83 691	48 522	75 589	81 402	54 185	17 664 863 675
2011	269 417	67 602	56 381	84 139	46 273	75 193	75 560	58 124	18 210 695 865
2012	289 262	70 309	60 824	83 254	48 640	78 646	80 488	57 565	20 337 602 818
2013	288 501	77 308	63 480	96 100	56 416	84 582	89 478	61 973	22 295 392 002
All years	3756 640	60 609	52 506	75 911	42 491	67 147	72 593	48 586	13 393 334 190
Annual change	+6511*	+1703*	+1121*	+2094*	+987*	+1967*	+1620*	+1354*	811 834 896*

*p<0.05 test for trend.
Costs are in 2010 dollars and include medical costs, work loss and quality-of-life loss.

number of adult cycling injuries increased by approximately 6500 (95% CI 4728 to 8287) annually. Total annual costs increased by 140% from $9.3 billion in 1997 to $22.4 billion in 2013. Each year, the total costs associated with non-fatal adult bicycle trauma increased by an average of $789 million (95% CI $647 to $930). Medical costs increased by 137% from $885 million in 1997 to $2.1 billion in 2013. Table 1 shows the mean total cost per case, stratified by age, sex and location of injury. On average, inflation-free costs due to riders older than 45 increased $2094 per case annually.

Medical, work loss and quality-of-life loss costs

Figure 1 shows the temporal trend in average medical, work loss and quality-of-life loss costs per adult patient. Linear regression by year shows an average increase per patient of $159 (95% CI $129 to $190) in medical costs, $387 (95% CI $291 to $482) in work loss and $1158 (95% CI $980 to $1336) in quality-of-life loss. On the US population level, this equates to an annual increase of $74 million (95% CI $59.8 to $81.1) in medical costs, $181 million (95% CI $146 to $216) in work loss and $534 million (95% CI $440 to $627) in quality-of-life loss.

Rider demographics

The proportion of total adult bicycle injury costs stratified by rider demographics can be seen in figure 2. The proportion of costs due to riders age 45 and older increased an average of 1.6% (95% CI 1.4% to 1.9%) annually. In 2013, 53.9% of total

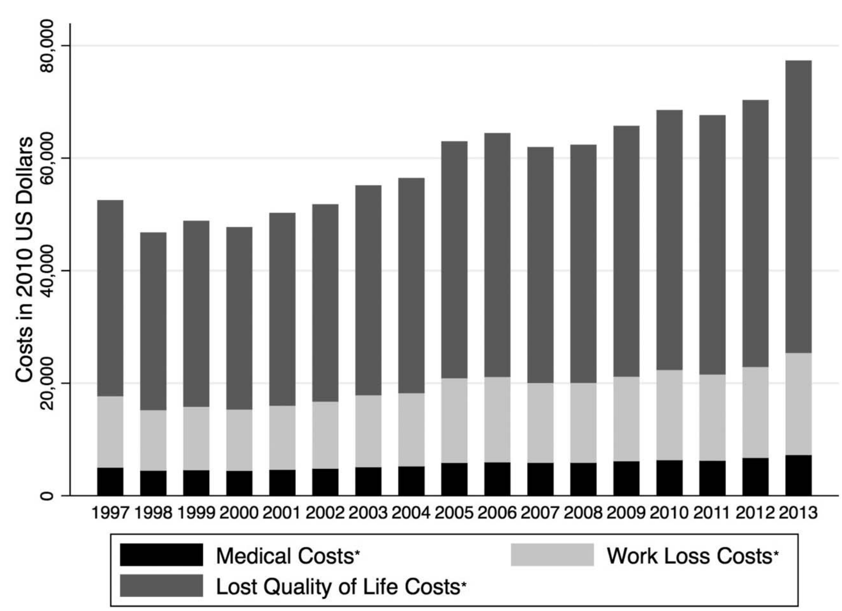

Figure 1 Inflation-free costs per case of non-fatal bicycle injury in the USA from 1997 to 2013 by medical, work loss and quality-of-life loss costs. *p<0.05 test for trend.

Downloaded from http://injuryprevention.bmj.com/ on August 29, 2017 - Published by group.bmj.com

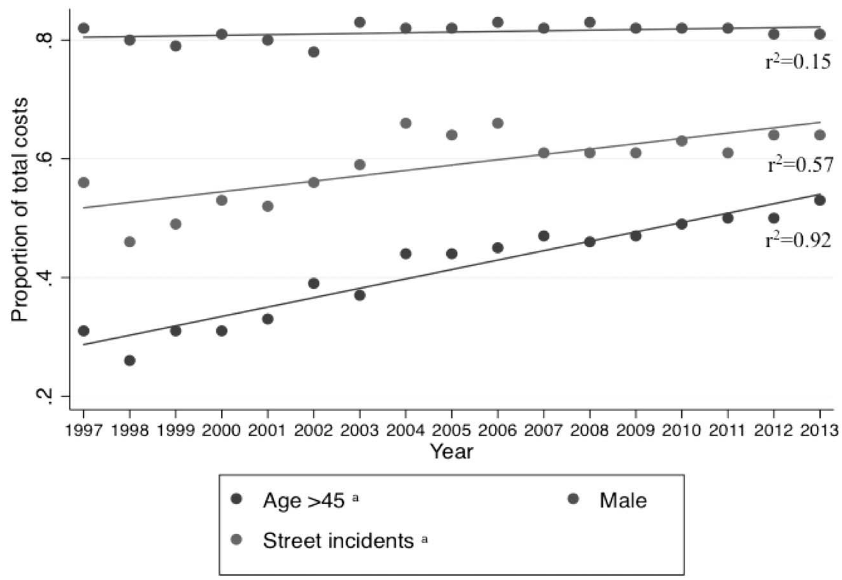

Figure 2 Proportion of total annual costs of non-fatal bicycle injuries associated with older age, male sex and injury on a street/highway, USA, 1997–2013. *p<0.05 test for trend.

costs were due to riders 45 and older, up from 26.0% in 1997 (107% increase). The proportion of costs due to incidents that occurred on a street or highway also steadily increased by 0.8% (95% CI 0.4% to 1.3%) annually. In 2013, 66.5% of total costs were due to bicycle injuries on the street, up from 46.0% in 1997 (45% increase). There was no significant linear trend by rider sex. In 2013, 77.3% of total costs were due to male riders.

Hospital versus ED admissions

Table 2 shows that adult hospital admissions increased significantly over time, with mean cost per case increasing by $2911 (95% CI $157 to $5666) annually. ED-treated adult injuries also significantly increased over time, with mean cost per case increasing by $374 (95% CI $332 to $417) annually.

Fatal injuries

Total costs

Total estimated costs due to fatal adult bicycle crashes were $39 billion from 1999 to 2013 (table 3). Total costs due to fatal injuries rose gradually by $28 million annually throughout the time period; they averaged $1.85 billion (1.5%) per year. Bicycling deaths increased by an average of 19 (95% CI 13 to 26) cases annually. Annual deaths due to bicycle crashes increased in patients age 45 and older (23 cases, 95% CI 19 to 27) and decreased in patients younger than 45 (14 cases, 95% CI 10 to 19). Cost per case steadily decreased by $28 280 (95% CI $22 086 to $34 475) annually.

Estimated adult bicycle injury costs totalled $24.4 billion in 2013. Estimated injury costs per mile bicycled fell from $2.85 in 2001 to $2.35 in 2009.

DISCUSSION

This study aimed to evaluate trends in costs associated with non-fatal and fatal bicycle injuries in the USA from 1997 to 2013 using incidence data from the federal databases and cost data based on published ICMs used in federal regulatory impact analysis.[9] Overall, costs due to non-fatal adult bicycle injuries increased steadily since 1997 by an average of $789 million annually. In 2013, we estimate adult bicycle injury costs totalled $24 billion. For reference, this is approximately double the medical and indirect costs associated with occupational illnesses in 1 year in the USA.[23] Injury costs of older riders and non-admitted injuries in street crashes increased disproportionately over time and raised total costs. Over time, men consistently accounted for three-quarters of total costs.

The increasing incidence of bicycle-related trauma and hospital admissions over the past 15 years only partly explained this increase in real injury costs.[6] Costs per survivor by treatment setting also rose. Regardless of the year of injury, the ICM used the same cost by age group and treatment setting for any given injury, for example, a compound tibia fracture. Thus, the cost increase must result from more severe injuries and older bicycle riders who may require longer recovery periods. Rising injury

Table 2 Incidence and mean cost per case per year for non-fatal bicycle injuries by hospital admission versus emergency department (ED), USA, 1997–2013

Year	Hospitalised incidence	Mean cost per case ($)	ED-treated incidence	Mean cost per case ($)
1997	10 885	438 542	166 390	27 239
1998	10 978	365 050	180 718	27 435
1999	11 600	363 372	180 968	28 663
2000	11 332	382 920	194 389	28 161
2001	11 416	407 189	196 509	29 494
2002	11 819	404 495	182 244	28 909
2003	12 684	401 963	174 885	29 975
2004	13 506	398 904	179 833	30 713
2005	14 637	455 027	176 171	30 397
2006	15 715	468 736	189 545	30 890
2007	17 168	426 306	203 881	31 256
2008	19 399	415 046	220 113	31 255
2009	20 481	436 525	224 287	31 851
2010	23 626	435 101	234 170	31 538
2011	23 725	429 358	245 630	32 661
2012	29 052	403 461	260 210	33 112
2013	31 020	437 872	257 324	33 842
All years	289 043	419 862	3 467 266	30 664
Annual change	+1206*	+2911*	+5302*	+374*

*p<0.05 test for trend.
Costs are in 2010 dollars and include medical costs, work loss and quality-of-life loss.

Downloaded from http://injuryprevention.bmj.com/ on August 29, 2017 - Published by group.bmj.com

Table 3 Incidence, mean cost per case and total annual cost by year for fatal bicycle injuries, USA, 1997–2013

	All adults		Age 18–44		Age≥45		All adults
Year	Incidence	Mean cost ($)	Incidence	Mean cost ($)	Incidence	Mean cost	Total cost ($)
1999	588	2870 523	333	3593 353	255	1926 592	1687 867 524
2000	548	2669 090	259	3576 971	289	1855 452	1462 661 320
2001	627	2775 113	307	3598 693	320	1984 992	1739 995 851
2002	613	2769 797	300	3567 844	313	2004 895	1697 885 561
2003	608	2679 188	273	3550 351	335	1969 255	1628 946 304
2004	684	2640 644	306	3563 083	378	1893 908	1806 200 496
2005	776	2658 060	330	3567 861	446	1984 889	2062 654 560
2006	812	2555 452	312	3585 578	500	1912 653	2075 027 024
2007	719	2597 008	293	3586 403	426	1916 509	1867 248 752
2008	796	2576 305	289	3649 265	507	1964 697	2050 738 780
2009	700	2453 056	238	3573 113	462	1876 057	1717 139 200
2010	718	2473 340	236	3651 371	482	1896 545	1775 858 120
2011	800	2478 918	266	3681 391	534	1879 933	1983 134 400
2012	850	2451 579	276	3635 790	574	1882 167	2083 842 150
2013	855	2430 732	273	3677 199	582	1846 050	2078 275 860
All years	10 694	2591 872	4291	3602 424	6403	1914 646	1847 831 727
Annual change	+19*	−28 280*	−3	+6952*	+23*	−5602	27 886 310

*p<0.05 test for trends in incidence, mean cost per case and total cost.
Costs are in 2010 dollars and include medical costs, work loss and quality-of-life loss.

severity is possibly caused by changes in motor vehicle traffic, increasing commuting by bicycle, or changes in vehicle design. Older riders accounted for a greater proportion of total costs through time and a larger share of inpatient admission costs.

Costs associated with cycling coincide with a rising exposure trend in both older adults and men.[24] The number of bicycle miles travelled per year by people age 45 and older increased from 1905 million in 2001 to 3645 million in 2009.[25] This corresponds to a 91% increase of exposure miles in 8 years in this age group. Similarly, a rising exposure can be seen in male cycling. The proportion of miles ridden by men rose from 0.73 in 2001 to 0.80 in 2009.[24] Thus, rising costs in these two demographic groups are driven by rising exposure.

Importantly, despite the rise in total injury costs, costs per mile bicycled by adults fell by 17% from 2001 to 2009. Unfortunately data are not available to assess if this fall resulted from increasing adult helmet use.

In addition to rising exposures, the increasing prevalence of older cyclists may be increasing costs due to more severe non-fatal injuries. Others have identified age over 39 as a risk factor for bicycle injury severity among admitted patients (OR=2.2 compared with younger adult patients).[26] Relative to younger riders, riders over age 55 have more than double the probability of dying if injured in a bicycle-MVC, an indication that this is a more vulnerable population.[27] An analysis of head injuries from bicycle crashes found that subdural haematomas, number of contusions, intracerebral haematomas and intraventricular bleeding increased with age.[28] With comparable injuries, age is also a risk factor for longer recovery times after injury.[29] The mechanisms causing higher injury severity among the elderly merit future research.

Street crashes represent an increasing proportion of total costs compared with non-street incidents. These crashes often involve motor vehicles, which increase velocity of crash impact and consequently injury severity.[26 27 30] Streets might also predispose to more injuries due to the coexisting environment with urban areas, increased population density or the presence of more unyielding street furniture.[31] Accumulating evidence suggests that bicycle-specific facilities, such as bicycle paths, may reduce crashes and injuries on the roadway.[4 32 33] Building such infrastructure is costly and the cost-effectiveness of such environmental health interventions often lack sufficient evidence for projects to move forward.[34] Projected costs to rebuild an entire 274-mile bikeway network in the city of Portland are $57 million,[35] which is about $208 000 per mile. The USA has an estimated 8 656 070 bicycle lane miles.[36] Thus, creation of a bikeway network covering one-sixth of the entire USA would cost approximately $300 billion, which roughly equals the total costs of non-fatal and fatal bicycle injuries in the 10-year study period ($293 billion). Although such infrastructure will not prevent all injuries, costs associated with injuries must be taken into account when determining the cost-effectiveness of bicycle-specific infrastructure.[37]

Total cost of adult bicycle fatalities steadily decreased over time. It is unclear if this resulted from shifts between age groups in frequency of bicycle use and miles bicycled. However, total cost per fatal injury is much larger in patients younger than 45 because work and quality-of-life losses fall as remaining life expectancy declines. Therefore, increasing rider age results in a falling mean cost of bicycle-related injuries. Decreased fatalities in younger riders might result from increased helmet use. Since 1980, the mortality rate due to no helmet use has decreased by an estimated 40%.[38]

The NEISS incidence data come from a sample of just 100 hospitals, which means that they might not be representative of the US population. The reliability of NEISS trend analyses, however, is enhanced because the same 100 hospitals were sampled over time. Injuries treated only in physician's offices or ambulatory clinics are not captured in the NEISS dataset so total cost was underestimated. The cost data came from multiple sources, with each presenting the possibility of measurement error and reporting bias. We deliberately ignored any medical cost changes resulting from technological change or inflation. Injury coding in the NEISS data is coarser than in the data sets underlying the medical cost estimates, which reduces the accuracy of the NEISS estimates and its sensitivity to severity changes

Downloaded from http://injuryprevention.bmj.com/ on August 29, 2017 - Published by group.bmj.com

over time. We also excluded costs of property damage, police and fire services, property insurance claims administration and injury-related litigation. We were unable to provide information about the heterogeneity of incidents or population density where bicycle injuries occur. Costs due to loss of life are challenging to estimate. The jury verdict method to value lost quality of life is imperfect and only estimates quality-of-life losses to the degree injuries in our study match those in litigation suits. Our total costs' estimates are thus influenced by choosing this method for predicting quality-of-life loss. Future studies should examine cost–benefit analyses for best practices to prevent injury and thus costs. In particular, roadway infrastructure and vehicle design might be incorporated in this analysis.

CONCLUSION

Costs per case of bicycle injury have risen steadily since 1997. The growing costs resulted from increasing injuries among riders age 45 and older and increases in street crashes. Society bears a large direct and indirect financial burden secondary to non-fatal and fatal bicycle injuries, suggesting a policy focus on injury prevention.

What is already known on the subject

- Over the last 15 years, the incidence of bicycle trauma in adults increased by 28%.
- In 2005, estimated medical and work loss costs due to fatal and non-fatal bicycle-related trauma exceeded $5 billion in the USA.

What this study adds

- Inflation-free costs per adult bicycle crash rose steadily from 1999 to 2013.
- The growing costs resulted from increasing ridership, share of injuries among riders age 45 and older, and proportion of street crashes.
- Costs per mile bicycled by adults fell from $2.85 in 2001 to $2.35 in 2009.
- Costs associated with adult bicycle crashes exceeded $24 billion in 2013, approximately double the medical and indirect costs of occupational injuries in the USA.

Contributors TWG: data analysis, interpretation of data, manuscript writing and editing. TAS: project idea, critical review of manuscript. MAA: data analysis, critical review of manuscript. ECO: interpretation of data, critical review of manuscript. GPM: interpretation of data, critical review of manuscript. BL: acquired all data, data analysis, interpretation of data, critical review of manuscript. TRM: acquired all data, data analysis, interpretation of data, critical review of manuscript. BNB: project idea, critical review of manuscript, supervision of project.

Funding This work was funded by the UCSF REAC-RAP programme and the Alafi Foundation.

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Raw data is available upon request of corresponding author ".

REFERENCES

1 Wen LM, Rissel C. Inverse associations between cycling to work, public transport, and overweight and obesity: findings from a population based study in Australia. *Prev Med* 2008;46:29–32.
2 Gordon-Larsen P, Nelson MC, Beam K. Associations among active transportation, physical activity, and weight status in young adults. *Obes Res* 2005;13:868–75.
3 Hamer M, Chida Y. Active commuting and cardiovascular risk: a meta-analytic review. *Prev Med* 2008;46:9–13.
4 Reynolds CC, Harris MA, Teschke K, *et al*. The impact of transportation infrastructure on bicycling injuries and crashes: a review of the literature. *Environ Health* 2009;8:47.
5 Chen WS, Dunn RY, Chen AJ, *et al*. Epidemiology of nonfatal bicycle injuries presenting to United States emergency departments, 2001–2008. *Acad Emerg Med.* 2013;20:570–5.
6 Sanford T, McCulloch CE, Callcut RA, *et al*. Bicycle trauma injuries and hospital admissions in the United States, 1998-2013. *JAMA.* 2015;314:947–9.
7 Miller TR, Lawrence BA, Jensen AF, *et al*. *The Consumer Product Safety Commission's revised injury cost model. Final report to the US Consumer Product Safety Commission*. Landover, MD: National Public Services Research Institute, 2000.
8 Naumann RB, Dellinger AM, Zaloshnja E, *et al*. Incidence and total lifetime costs of motor vehicle–related fatal and nonfatal injury by road user type, United States, 2005. *Traffic Inj Prev* 2010;11:353–60.
9 Miller TR, Zaloshnja E, Lawrence BA, *et al*. Pedestrian and pedalcyclist injury costs in the United States by age and injury severity. *Annu Proc Assoc Adv Automot Med* 2004;48:265-84.
10 Schulman J, Sacks J, Provenzano G. State level estimates of the incidence and economic burden of head injuries stemming from non-universal use of bicycle helmets. *Inj Prev* 2002;8:47–52.
11 Hamann C, Peek-Asa C, Lynch CF, *et al*. Burden of hospitalizations for bicycling injuries by motor vehicle involvement: United States, 2002 to 2009. *J Trauma Acute Care Surg* 2013;75:870–6.
12 Lopez DS, Sunjaya DB, Chan S, *et al*. Using trauma center data to identify missed bicycle injuries and their associated costs. *J Trauma Acute Care Surg* 2012;73:1602–6.
13 U.S. Consumer Product Safety Commission. NEISS: National Electronic Injury Surveillance System, A Tool for Researchers 2000. 2000. http://www.cpsc.gov// PageFiles/106626/2000d015.pdf (accessed 12 Oct 2016).
14 National Vital Statistics System. 2016. http://www.cdc.gov/nchs/nvss/deaths.htm (accessed 12 Oct 2016).
15 Classification of diseases (ICD). 2016. http://www.who.int/classifications/icd/en/ (accessed 12 Oct 2016).
16 Lawrence BA, Spicer RS, Miller TR. A fresh look at the costs of non-fatal consumer product injuries. *Inj Prev* 2015;21:23–9.
17 Lawrence BA, Miller TR, Jensen AF, *et al*. Estimating the costs of non-fatal consumer product injuries in the United States. *Int J Inj Contr Saf Promot.* 2010;7:97–113.
18 Cohen MB, Miller TR. Willingness to award non-monetary damages and the implied value of life from jury awards. *Int Rev Law Econ* 2003;23:165–81.
19 Miller TR, Cohen MA, Hendrie D. Non-economic damages due to physical and sexual assault: estimates from civil jury awards. *Forens Sci Crim* 2017;2:1.
20 Cook PJ, Ludwig J. *Gun violence: the real costs*. New York: Oxford University Press, 2000.
21 U.S. Department of Justice. Prison Rape Elimination Act, Regulatory Impact Assessment. 2012. http://ojp.gov/programs/pdfs/prea_ria.pdf (accessed 22 Feb 2017).
22 Medical and Work Loss Cost Estimation Methods for the WISQARS Cost of Injury Module. 2014. http://www.pire.org/documents/WisqarsCostMethods.pdf (accessed 12 Oct 2016).
23 Leigh J. Economic burden of occupational injury and illness in the United States. *Milbank Q* 2011;89:728–72.
24 Lachapelle U. Walk, bicycle, and transit trips of transit-dependent and choice riders in the 2009 United States National Household Travel Survey. *J Phys Act Health* 2015;12.
25 U.S. Department of Transportation, Federal Highway Administration, 2009 National Household Travel Survey. 2009. http://nhts.ornl.gov (accessed 16 Oct 2016).
26 Rivara FP, Thompson DC, Thompson RS. Epidemiology of bicycle injuries and risk factors for serious injury. 1997. *Inj Prev* 2015;21:47–51.
27 Kim JK, Kim S, Ulfarsson GF, *et al*. Bicyclist injury severities in bicycle-motor vehicle accidents. *Accid Anal Prev* 2007;39:238–51.
28 Depreitere B, Van Lierde C, Maene S, *et al*. Bicycle-related head injury: a study of 86 cases. *Accid Anal Prev* 2004;36:561–7.
29 Carroll L, Cassidy JD, Peloso P, *et al*. Prognosis for mild traumatic brain injury: results of the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehabil Med* 2004;36:84–105.
30 Rivara FP, Thompson DC, Thompson RS. Epidemiology of bicycle injuries and risk factors for serious injury. *Inj Prev* 1997;3:110–14.
31 Chaney RA, Kim C. Characterizing bicycle collisions by neighborhood in a large Midwestern city. *Health Promot Pract* 2014;15:232–42.

Downloaded from http://injuryprevention.bmj.com/ on August 29, 2017 - Published by group.bmj.com

32 Davidson JA. Epidemiology and outcome of bicycle injuries presenting to an emergency department in the United Kingdom. *Eur J Emerg Med* 2005;12:24–9.
33 Pucher J, Buehler R. Making cycling irresistible: lessons from the Netherlands, Denmark and Germany. *Transp Rev* 2008;28:495–528.
34 Cavill N, Kahlmeier S, Rutter H, *et al*. Economic analyses of transport infrastructure and policies including health effects related to cycling and walking: a systematic review. *Transp Pol* 2008;15:291–304.
35 Gotschi T. Costs and benefits of bicycling investments in Portland, Oregon. *J Phys Act Health* 2011;8(Suppl 1): S49–58.
36 Estimated U.S. Roadway Lane-Miles by Functional System. U.S. Department of Transportation, 2015. http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_01_06.html (accessed 16 Oct 2016).
37 Chen L, Chen C, Srinivasan R, *et al*. Evaluating the safety effects of bicycle lanes in New York City. *Am J Public Health* 2012;6:1120–7.
38 Cummings P, Rivara FP, Olson CM, *et al*. Changes in traffic crash mortality rates attributed to use of alcohol, or lack of a seat belt, air bag, motorcycle helmet, or bicycle helmet, United States, 1982–2001. *Inj Prev* 2006;12:148–54.

Downloaded from http://injuryprevention.bmj.com/ on August 29, 2017 - Published by group.bmj.com

Estimated total costs from non-fatal and fatal bicycle crashes in the USA: 1997–2013

Thomas W Gaither, Thomas A Sanford, Mohannad A Awad, E Charles Osterberg, Gregory P Murphy, Bruce A Lawrence, Ted R Miller and Benjamin N Breyer

Inj Prev published online June 1, 2017

Updated information and services can be found at:
http://injuryprevention.bmj.com/content/early/2017/04/24/injuryprev-2016-042281

These include:

References This article cites 28 articles, 5 of which you can access for free at:
http://injuryprevention.bmj.com/content/early/2017/04/24/injuryprev-2016-042281#BIBL

Email alerting service Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections Articles on similar topics can be found in the following collections

Press releases (38)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/