ORIGINAL ARTICLE

State level estimates of the incidence and economic burden of head injuries stemming from non-universal use of bicycle helmets

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Objective: To develop national and state level estimates for preventable bicycle related head injuries (BRHIs) and associated direct and indirect health costs from the failure to use bicycle helmets.
Methods: Information on the effectiveness and prevalence of use of bicycle helmets was combined to estimate the avoidable fraction, that is, the proportion of BRHIs that could be prevented through the use of bicycle helmets. The avoidable fraction multiplied by the expected number of BRHIs gives an estimate of the number of preventable cases. Direct and indirect health costs are estimated from a social perspective for the number of preventable BRHIs to assess potential cost savings that would be achieved if all riders wore helmets.
Results: Approximately 107 000 BRHIs could have been prevented in 1997 in the United States. These preventable injuries and deaths represent an estimated $81 million in direct and $2.3 billion in indirect health costs. Estimates range from 200 preventable BRHIs and $3 million in health costs in Wyoming (population 480 000) to 13 700 preventable BRHIs and $320 million in health costs in California (population 32.3 million).
Conclusions: A number of successful approaches to increasing bicycle helmet use exist, including mandatory use laws and community based programs. The limited use of these strategies may be related to the fact that too little information is available to state agencies about the public health and economic burden of these preventable injuries. In conjunction with information on program costs, our estimates can assist state planners in better quantifying the number of preventable BRHIs and the costs and benefits of helmet promotion programs.

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Each year in the US, nearly 700 persons die from bicycle crashes[1] and 567 000 more are treated in emergency departments.[2] About two thirds of these fatalities and one third of these injuries are related to a head injury.[3 4] Although bicycle helmets substantially reduce the risk such injuries,[5–7] the majority of bicyclists do not always wear helmets.[8 9]

One reason for the limited use of successful strategies to increasing bicycle helmet use[10] may be related to the dearth of information at the state level about the public health burden and associated health costs of these preventable injuries. This information could demonstrate to decision makers that promoting helmet use could be a cost saving investment. Accordingly, we report national and state specific estimates of preventable bicycle related head injuries (BRHIs) and the associated health costs for 1997. We also discuss methodological issues and data gaps encountered in developing these estimates.

METHODS

We use four steps in the estimation process (fig 1). State level population estimates are multiplied by the corresponding national death, hospitalization, and emergency department visit rates to generate the expected number of cases. The proportion of cases that could be prevented—the avoidable fraction—is estimated by combining information on helmet effectiveness and prevalence of use. The avoidable fraction is multiplied by the expected number of injuries to estimate the number of avoidable cases of fatal and non-fatal injuries. We then estimate the direct health costs of medical treatment and the indirect health costs due to losses in productivity from premature death and permanent disability for the avoidable cases.

Because of a lack of information on state specific BRHI incidence,[11] state level incidence estimates are obtained by applying national rates to state population data. Associated state level health cost estimates are developed from both state and national data.[12]

An incidence based, cost-of-injury approach is used to estimate the "lifetime" economic burden of BRHIs, including all direct costs for medical care and the indirect costs related to lost productivity due to disability or premature death associated with the injury.

All incidence and cost estimates are for 1997. These are characterized by their presentation as: fatalities, non-fatal hospitalized cases, and non-hospitalized emergency department cases.

Estimating the expected number of cases

We used National Center for Health Statistics (NCHS) multiple cause of death files from 1993–95 to estimate the incidence of fatal BRHIs[13] by selecting deaths with bicycle related external cause of death and associated N codes suggestive of head injury.[3 4] The *International Classification of Diseases* (ICD)-9 N and E codes included: 800–801.9; 803; 804; 850.0–854.9; 905.0; 907.0; E800-E807 with a fourth digit of 0.3; E810–E819 and E820–E825 with a fourth digit of 0.6; E826.1; and E827–E829 with a fourth digit of 0.1. Because NCHS data are too sparse when subdivided by state, age, and gender, we pooled the three years of national level data to produce stable age and gender-specific rates that were applied to 1997 state population figures.

Abbreviations: AIS, abbreviated injury scale; BRHI, bicycle related head injuries; HCUP, Healthcare Cost and Utilization Project; NCHS, National Center for Health Statistics; NEISS, National Electronic Injury Surveillance System

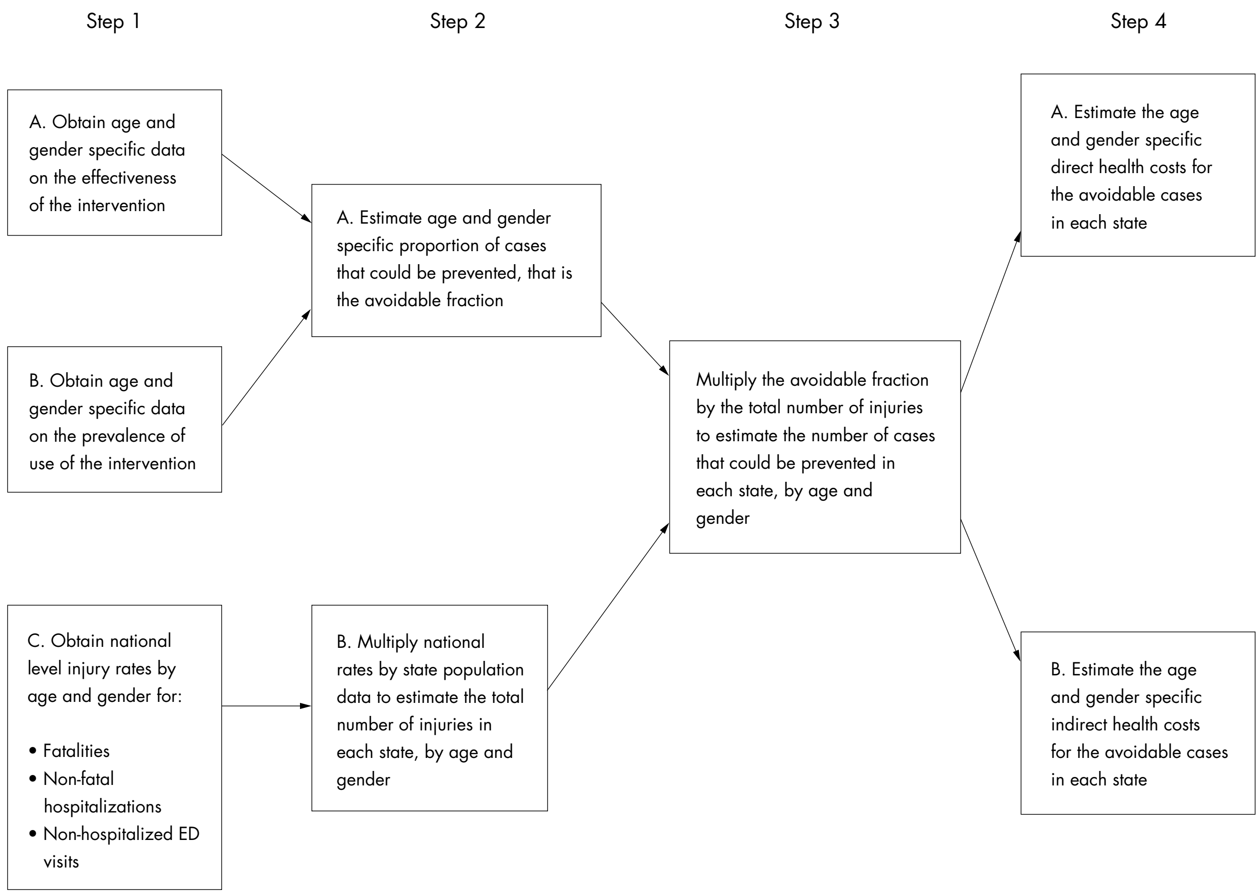

Figure 1 Estimation process (ED = emergency department).

The national incidence of non-fatal hospitalized BRHIs is estimated using the 1994 Healthcare Cost and Utilization Project (HCUP) database,[14] which consists of uniform hospital discharge records from 17 states. To identify BRHIs, 15 diagnosis fields were searched for the same ICD-9 N codes and E codes used to identify fatalities. All records with a BRHI noted in any of the 15 diagnosis fields are included. To ensure unbiased incidence estimates, we only include nine states with at least 80% of their head injury records E coded. In eliminating eight of the 17 states, 510 hospitals, 686 BRHIs, and approximately 3.3 million hospital discharge records were eliminated. Because the HCUP database is designed to support national level estimates and survey weights are provided for this purpose, weighting adjustments were made to compensate for the loss of cases in non-E code states.

Data from the 1993–95 Consumer Product Safety Commission's National Electronic Injury Surveillance System (NEISS) was used to estimate the national rate of emergency department visits.[15] We identified bicycle related injuries using the product code field, and head injury using the body part field (which notes the most severely injured part). Head injury included injury to the eye, ear, face, and head because these injuries are preventable with bicycle helmets.[6 16]

Estimating the avoidable fraction and the number of avoidable cases

Age specific avoidable fractions were assumed constant for fatalities, non-fatal hospitalizations, and non-hospitalized emergency department visits, and estimated as[17]:

$$\text{Avoidable fraction} = \frac{p(RR-1}{p(RR-1)+1}$$

where p is the proportion of riders who do not use helmets and RR is the relative risk of BRHI for those who do not use helmets compared with those who do.

The proportion of riders who use helmets in a particular age group ($1-p$) is assumed to be 31.8% for those less than 10 years of age, 17.5% for those 10–14 years old, 7.5% for 15–19 year olds, 19.2% for 20–64 year olds, and 18.6% for those older than 65.[8 9] The relative risk is assumed to be 3.23 regardless of age or gender.[6]

In each state, the number of avoidable cases for each age and gender group is obtained by applying the age specific avoidable fractions to the age and gender specific expected numbers of BRHI.

Estimating the direct health costs for the avoidable cases

The direct health costs associated with the avoidable cases are estimated separately for fatalities, non-fatal hospitalized cases, and emergency department visits. Included are the costs of health care services used in acute and rehabilitative phases of treatment: inpatient hospital services, services of health professionals, those provided in emergency departments and outpatient clinics, and physical and vocational rehabilitation. We do not include costs for outpatient pharmaceuticals, long term care, home health care, medical supplies and devices, and patients' time costs in accessing these services. Because the distributions of costs are right skewed, the geometric mean for each cost category is estimated.

Fatalities

Medical expenses for fatally injured persons vary by the length of time between injury and death. Three situations are considered: (1) those who die at the scene of the crash or in transit from the crash to the hospital, (2) those who die in the emergency department, and (3) those who die after hospital admission.

Because data on the costs of paramedic and emergency transport services are not systematically collected by cause and type of injury, and because the literature contains only a few estimates of these costs for head injuries that are based on small samples of patients with very severe head injuries,[18] these costs were not included.

Estimates of average emergency department treatment costs were developed from charges included in emergency department encounters for BRHIs from the state of Missouri for 1994 and 1995. Charges per encounter were converted to costs using a case weighted average operating cost-to-charge ratio for urban Missouri hospitals.[19] Patient's disposition at discharge (for example, discharged home, admitted to hospital, died) is not noted in these data, thus, the same average cost estimate is used for each disposition.

The direct health costs for persons who die in the hospital are assumed to include: (1) inpatient services, (2) physicians' fees, and (3) emergency department costs. The HCUP database is used to estimate total hospital charges per discharge at the national level. Costs per discharge are estimated from charges using 1994 state level, case weighted average operating cost-to-charge ratios for urban and rural hospitals.[19] As the cause of a head injury should have little bearing on whether the record is E coded, discharge records from all 17 states in the HCUP database are used to improve the precision of the estimates. Physician fees are estimated as 39% of the costs of the index admission.[20] State specific estimates of hospital costs and physician fees are derived using state-to-national ratios for hospital costs per admission

Table 1 Estimating the number of avoidable fatal and non-fatal cases of BRHI in 1997 and the associated direct and indirect health costs

	No of avoidable cases			Total health costs ($, in thousands)	
United States	Fatalities (n=327)	Hospitalized cases (n=6884)	ED cases (n=99894)	Direct ($81212)	Indirect ($2288320)
Alabama	7	106	1543	1154	32067
Alaska	0	18	269	248	5679
Arizona	7	119	1796	1361	37388
Arkansas	3	66	938	6397	17093
California	42	849	12841	10812	311114
Colorado	5	102	1461	1206	34895
Connecticut	5	81	1168	932	36717
Delaware	0	17	260	200	5045
Florida	17	359	5071	4393	102741
Georgia	11	197	2848	2162	64035
Hawaii	0	32	440	400	8262
Idaho	0	35	485	324	7963
Illinois	15	306	4520	3810	110767
Indiana	8	149	2146	1693	45847
Iowa	3	76	1031	842	20550
Kansas	3	69	975	789	19602
Kentucky	5	99	1391	1026	28584
Louisiana	6	116	1670	1292	33498
Maine	0	32	436	336	7083
Maryland	8	127	1861	1456	45852
Massachusetts	8	151	2151	1879	59407
Michigan	13	251	3617	3058	89842
Minnesota	8	124	1780	1403	44105
Mississippi	4	73	1049	678	19624
Missouri	8	139	2004	1645	43802
Montana	0	24	328	238	4845
Nebraska	2	46	627	491	12581
Nevada	2	43	637	514	13925
New Hampshire	0	33	432	344	8870
New Jersey	11	204	2908	2442	84280
New Mexico	2	46	697	509	12589
New York	20	453	6626	6383	190160
North Carolina	10	189	2723	2122	55885
North Dakota	0	17	233	174	13551
Ohio	14	285	4079	3292	90232
Oklahoma	5	87	1245	912	24605
Oregon	5	83	1170	883	27768
Pennsylvania	14	300	4191	3547	97811
Rhode Island	0	24	343	277	6067
South Carolina	5	96	1382	1126	27437
South Dakota	0	19	278	201	3873
Tennessee	8	135	1926	1480	41359
Texas	23	518	7793	5870	169135
Utah	3	59	920	602	17867
Vermont	0	15	212	156	3499
Virginia	9	169	2417	1941	54772
Washington	8	146	2097	1637	49748
West Virginia	2	45	602	483	11763
Wisconsin	8	135	1924	1455	41906
Wyoming	0	13	185	126	2747

ED, emergency department.

and physician practice costs.[21 22] Emergency department costs for persons who died after admission to the hospital are estimated, as are the costs for those who died in the emergency department, using encounter data from the state of Missouri.

To estimate costs for each type of fatality, we assumed that approximately 50% of the deaths occurred at the scene of the injury or in transit, 30% occurred in the emergency department, and 20% after hospital admission.[23]

Non-fatal hospitalized cases

The direct health costs for non-fatal hospitalized avoidable cases are assumed to include: (1) emergency department costs; (2) hospital costs and physician fees for the initial admission and inpatient rehabilitation; (3) outpatient rehabilitation; and (4) costs for subsequent hospitalizations.

As for fatalities, estimates of the average emergency department costs for non-fatal hospitalized cases are developed from emergency department encounter records from Missouri, and national average inpatient costs are estimated by applying cost-to-charge ratios to the charges included in the HCUP data. The remaining components for non-fatal hospitalized avoidable cases are estimated as a per cent of the costs of the index admission: 39.0% for professional fees; 4.7% for subsequent hospitalizations; 3.4% for inpatient rehabilitation; and 2.7% for outpatient rehabilitation.[20]

Emergency department cases

As discussed above, the average emergency department costs for BRHIs treated and released from the emergency department is the same as for patients who died or who were admitted to the hospital following an emergency department encounter.

Estimating the indirect costs for the avoidable cases

To estimate productivity losses at the state level, we modified the human capital approach for prevention effectiveness.[24] For each state, age and gender specific estimates of indirect costs were estimated using state level data on average wages, employment, and labor force participation by age and gender. The individual age-gender estimates were summed to obtain the overall state estimate. Because not all of these data elements are available by race, we could not make state specific, age and gender estimates by race. Annual productive value is estimated as the sum of annual earnings, including fringe benefits and annual imputed value of housekeeping services. Economic valuation for lost leisure time and pain and suffering are not included because methods for quantifying these outcomes in monetary terms are not well developed. Similarly, productivity losses for partial disability are not included. With death or permanent total disability, annual losses are accrued over the remaining years of a person's expected lifetime and discounted to present values at a 3% discount rate.[25] For children and adolescents who are not yet in the labor force, the value of future lost work time is estimated in terms of projected lifetime earnings using the annual wages and salaries of current workers and an estimated annual increase in non-farm labor productivity of 1.7%.

Estimates for adults are based on rates of "failure to return to work" observed in follow up studies of workers who suffered severe head injuries.[26–30] Because injury severity is an important predictor of time to return to work and the proportion of injured persons who never return to work, the severity of injury for each discharge record in HCUP was quantified using the abbreviated injury scale (AIS).[31] The age and AIS specific distribution of cases from HCUP was multiplied by the AIS specific estimates of failure to return to work from the literature to estimate the severity adjusted age specific per cent of cases who fail to return to work. The rates of failure to return to work observed in the studies of adults are assumed to occur among children once they reached working age. We assume that if an individual did not return to work after two years, he or she is likely to remain permanently unemployed due to disability.

Sensitivity analysis

We explored the effects of modifying key parameters including: (1) estimating the incidence of non-fatal hospitalized cases using HCUP principal diagnosis versus any diagnosis of BRHI; (2) estimating the incidence of hospitalized injuries using NEISS data versus HCUP; (3) varying the relative risk; (4) varying the discount rate to estimate the expected lifetime productivity losses for fatalities and for non-fatal hospitalized cases; (5) using data from Seattle, Washington, to estimate emergency department rates versus the NEISS [15]; and (6) varying assumptions about the per cent of non-fatal hospitalized cases who either go, or return, to work after a BRHI.

RESULTS

This study estimated that, in the US, approximately 327 fatal, 6900 hospitalized, and 100 000 ED cases of BRHI could have been avoided in 1997 with universal use of bicycle helmets (table 1). These preventable cases are associated with more than $81 million in direct and $2.3 billion in indirect health costs. Estimates range from 200 preventable BRHIs and $3 million in health costs in Wyoming (population 480 000) to 13 700 preventable BRHIs and $320 million in health costs in California (population 32.3 million).

Both the number of cases and the direct and indirect health costs are extremely sensitive to changes in the relative risk (table 2). The number of avoidable cases in 1997 in the US ranges from approximately 56 000 to 139 000 and the total health costs range from $1.3 to $3 billion depending on the choice of relative risk. Lifetime indirect health costs are

Table 2 Sensitivity analysis of the effects on the national estimates of modifying key parameters

	No of avoidable cases			Total health costs ($, in thousands)	
Key parameters	Fatalities	Hospitalized cases	ED cases	Direct	Indirect
Baseline*	327	6884	99894	$81212	$2288320
HCUP[14] principal diagnosis of BRHI	327	5185	99894	$68533	$1839168
RR = 1.65[7]	176	3676	52351	$44844	$1222911
RR = 6.67[5]	419	8808	129287	$103055	$2931185
Discount rate of 1%	327	6884	99894	$81212	$3917906
Discount rate of 5%	327	6884	99894	$81212	$1523224
Hospitalization rates based on NEISS[2]	327	5780	99894	$72091	$2026867
ED rates based on Thompson et al. (1990)[17]	327	6884	89115	$79712	$2288320

ED, emergency department; RR, relative risk. *Baseline scenario assumes NCHS death rates, HCUP rates for any diagnosis of BRHI, NEISS ED rates, RR = 3.23, and discount rate of 3%.

extremely sensitive to changes in the discount rate. The 1997 lifetime indirect health costs at the national level range from $1.5 billion for a discount rate of 5%, to $3.9 billion for a discount rate of 1%.

DISCUSSION

We estimate that if all riders wore helmets, approximately 107 000 BRHIs—and the associated $2.4 billion direct and indirect health costs—could have been avoided in the US in 1997. Even using the most conservative assumptions, 56 000 BRHIs could have been prevented, for a total health cost saving of $1.3 billion. Our estimates do not include economic valuation for lost leisure time, pain, and suffering. Human capital estimates are smaller than injury cost estimates that take these aspects of injury into account.[32]

Being comprehensive in estimating the costs and benefits of injury is essential for analyses conducted from the social perspective when economic comparisons are needed among a number of diverse injury prevention interventions, for example, bicycle helmets, smoke detectors, and seat belts.[25] It is our view that analyses conducted from a governmental perspective are also useful for planners.

Numerous methodological issues and data gaps face anyone attempting to generate analogous state level estimates for other injury prevention interventions (fig 1):

Need for state level estimates (steps 1–4)

Because of the lack of state level data systems, estimates for helmet use prevalence, incidence, and costs were generated using national data. Geographic variation in BRHI incidence is likely, however, because of variability in the prevalence of helmet use and in bicycle riding patterns related to weather.

Temporal effects (steps 1B, 1C, 4)

Without periodic updating, estimates quickly become outdated. For example, a change in the use of the intervention over time affects not only estimates of prevalence of use, but also estimates of expected injury incidence rates, and severity and disability distributions. Similarly, many of the data needed to develop the components of direct and indirect health costs vary over time, for example, medical care costs, wages, and the proportion of the population employed. Because specific types or causes of injuries are relatively rare (for example, BRHIs), pooling several years of data may be necessary to achieve stable estimates, but this may mask time trends.

Need for age and gender specific estimates (steps 1, 4)

Incidence rates, direct and indirect health costs, prevalence of use of the intervention, and effectiveness of the intervention may vary by age and gender. Similarly, control efforts often target particular segments of the population.

Unavailable data (steps 1C, 4)

Many data needed are not readily available from state or national sources. For example, although large numbers of non-fatally injured persons are initially treated in outpatient departments, physicians' offices, and other ambulatory care settings, encounter data from these settings do not generally include E codes to identify the external cause of injury. Similarly, several treatment cost categories, including paramedic and emergency transport costs and costs for long term care, are not available. It is often impossible to distinguish subsets of persons whose risk for injury varies. For example, early adopters of an intervention may have a different level of risk of injury than do late adopters, and the costs may be different as well, because early adopters tend to have less severe injuries. It is often necessary to extrapolate from highly selected series of patients that are not representative of the situation for which an estimate is needed. We used studies of return-to-work in severely injured adults to estimate the likelihood that a child would be permanently disabled.

Key points

- Too little information is available to state agencies about the public health and economic burden of preventable bicycle related head injuries (BRHIs).
- We estimated that, in the US, approximately 327 fatal, 6900 hospitalized, and 100 000 emergency department cases of BRHI could have been avoided in 1997 with universal use of bicycle helmets. These preventable cases are associated with more than $81 million in direct and $2.3 billion in indirect health costs.
- Even using the most conservative assumptions, 56 000 BRHIs could have been prevented in the US, for a total health cost saving of $1.3 billion.
- Estimates range from 200 preventable BRHIs and $3 million in health costs in Wyoming (population 480 000) to 13 700 preventable BRHIs and $320 million in health costs in California (population 32.3million).
- In conjunction with information on program costs, these estimates can assist state planners in better quantifying the number of preventable BRHIs and the costs and benefits of helmet promotion programs.
- Numerous methodological issues and data gaps face anyone attempting to generate analogous state level estimates for other injury prevention interventions.
- We believe that the debate in injury, and disease prevention, needs to shift from total burden to preventable burden.

Non-comparability of existing data sources (steps 1, 4)

Obtaining comparable figures is a challenge because existing data sources use different case definitions, measures of severity, referent years, and age groupings.

Multiple injuries (step 4A)

Decisions must be made about how to apportion costs for a BRHI if a person has multiple injuries and conditions.

Defining the intervention (step 1B)

There are distinctions between the intervention and the system of intervention delivery and between the efficacy (ideal circumstance) and the effectiveness (real world results) of both. We define the intervention as a bicycle helmet that is worn; a law mandating its use would be a delivery system. Either could be modeled, assuming that the post-intervention prevalence of the risk factor can be defined.

Valuation of time for groups for whom there are no directly comparable labor market experiences, that is, the elderly, children, and those unable to work (step 4B)

For a cost-of-injury assessment of a health and safety intervention, the appropriate measures of the opportunity cost of time are the wage rates of the individuals for whom the intervention is targeted. Implementing this approach presents problems for groups for whom there are no wage data. Practical alternatives and further research into methods for valuing the time of these groups are needed.

IMPLICATIONS FOR PREVENTION

While we are making estimates of the incidence and economic burden of BRHIs for the US and the individual states, the problem is well documented internationally.[33 34] We highlight these methodological issues because we believe that the debate in injury, and disease prevention, needs to shift from total burden to preventable burden. Using this model we hope to generate state level estimates of the numbers of preventable hospitalized and non-hospitalized cases and deaths for other types of injuries, along with the associated direct and indirect health costs from the failure to use available injury control interventions. In conjunction with information on program costs, such estimates can assist planners in better quantifying the preventable burden of injury and examining the costs and benefits of injury prevention programs.

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