Health and Economic Burden of Traumatic Brain Injury: Missouri, 2001–2005

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SYNOPSIS

Objective. We examined the financial and social costs resulting from traumatic brain injury (TBI) in Missouri.

Methods. We computed mortality rates from death certificates, the direct cost of TBI from hospital and emergency department (ED) visit charges, the social cost in terms of years of potential life lost (YPLL) using an abridged Missouri life table, and the indirect financial cost in terms of lost productivity due to premature death for all TBI and four major causes of TBI in Missouri.

Results. During 2001–2005, a mean of 1,358 lives were lost due to TBI in Missouri. Four major causes—unintentional falls, motor vehicle traffic crashes, motorcycle crashes, and firearms—accounted for 88% of all TBI deaths. We estimated the annual direct medical cost of TBI at $95 million, or about $1.67 million per 100,000 Missourians. This cost increased by about 60% between 2001 and 2005. The four major causes of TBI accounted for 68% of all direct medical costs of TBI. We estimated the cost per hospitalization and ED visit at $6,948 and the indirect social cost at 48,501 YPLL. During this period, the mean age of TBI fatality was 44 years. We determined the lost productivity due to TBI mortality—$1.1 billion, or about $18.8 million per 100,000 Missourians—to be three times as high for males as for females.

Conclusions. The types of costs covered in this study underestimated the total cost of TBI in Missouri, as we did not include outpatient care, rehabilitation, and drug costs. Nevertheless, we found the health and economic burden from medical care and mortality related to TBI to be substantial in Missouri.

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Traumatic brain injury (TBI) is an insult to the brain that can result in impairments and disabilities, often leading to considerable loss of independence, productivity, and income potential. Missouri has seen a troubling increase of 17% in combined emergency department (ED) visits and hospitalizations related to TBI (from 203.5 per 100,000 in 1998 to 237.8 per 100,000 in 2005) (Figure 1). In Missouri, TBI accounted for 2.3% of all injuries annually from 2001 to 2005.[1] However, these numbers likely underestimate the true picture, as they do not include an estimate of the number of people who experienced a TBI and sought other or no medical care.

Although all types of falls were the most common cause of TBI, for this analysis we included the mortality and indirect costs for only unintentional falls to ascertain easily preventable types of injuries in this category. The second most common cause of TBI—motor vehicle traffic crashes—includes injuries to pedestrians, bicyclists, and occupants of cars, trucks, and other vehicles, excluding motorcycle-related TBI. We made this a third category because it is an important safety legislation issue. The fourth category included all types of firearms-related TBI.

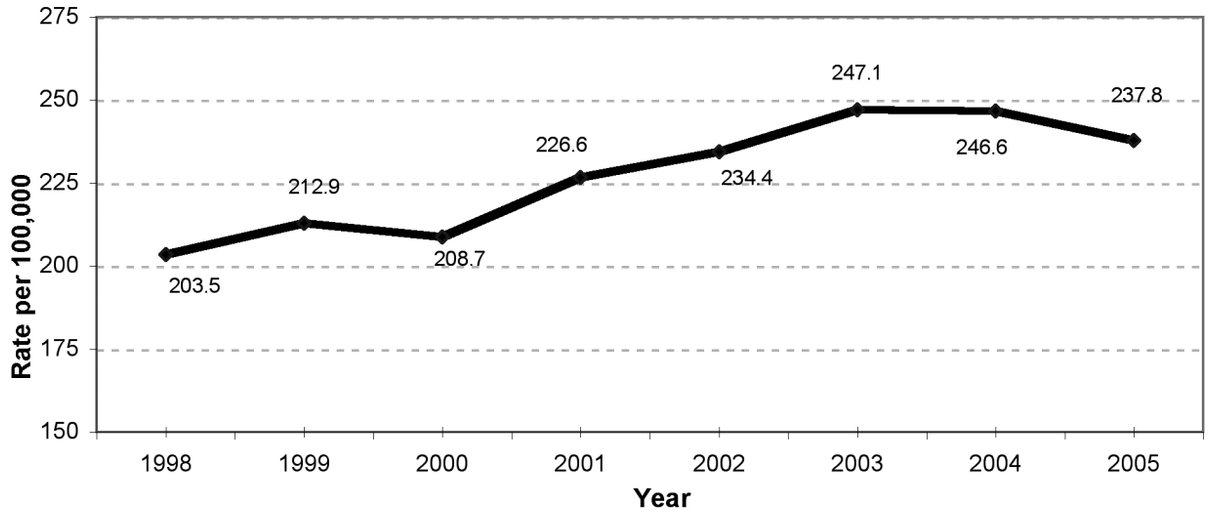
Several components of costs are associated with TBI. A person might recover fully from TBI, he or she might become partially or completely disabled, or the TBI might result in death. If a person with TBI recovers from the injury and is sent home, there are short-term costs due to ED visits, costs for follow-up visits to physicians or hospital charges (e.g., direct costs), and lost earnings (e.g., indirect costs). If the person becomes partially or fully disabled, there are additional long-term costs due to acute, skilled nursing or intermediate care, rehabilitation, or hospice. In the case of death, there are two major types of costs: (*1*) years of potential life lost (YPLL), which is the social cost, and (*2*) productivity loss, which is the indirect economic cost.

The disposition of TBI patients in Missouri during 2001–2005 is presented in Figure 2. TBI creates a significant public health burden, both nationally and within the state of Missouri, when the number of events, short- and long-term consequences, and costs are considered.

Despite the known burden due to TBI, the actual social and economic costs associated with TBI are largely unknown in Missouri. This insufficient information limits total comprehension of the magnitude of the TBI problem in Missouri and, thus, hinders public health actions to prevent TBI. This study sought to estimate the direct financial and social costs resulting from TBI in Missouri.

The types of costs covered in this study underestimated the total cost of TBI, as we did not include outpatient care, rehabilitation, and drug costs. Because we assessed the overall impact of TBI in Missouri, we did not use the classification of TBI by severity (severe, moderate, mild, and fatal). A 2001 study by Kreutzer et al. used a different classification to assess the cost of TBI. In that classification, they estimated the cost of acute and rehabilitation care associated with TBI.[2]

Figure 1. Traumatic brain injury rate for emergency department visits and hospitalizations for Missouri residents, 1998–2005[a]



[a]Age-adjusted rate using U.S. 2000 standard population.

METHODS

This study used the macro (i.e., aggregate numbers) approach rather than the traditional micro (i.e., individual case/visit) approach to assess the overall burden of the injury. We presented all TBIs in the four major causes: motor vehicle traffic crashes, firearms, unintentional falls, and motorcycle crashes. We considered motorcycle crashes a separate category due to the safety issue related to helmet laws and the great potential to prevent TBI caused by motorcycle crashes in Missouri. TBI related to unintentional falls was another major issue due to increased occurrences among younger and older Missourians. We excluded other types of falls because we wanted to focus on understanding preventable types of falls.

Data sources

We obtained TBI-related hospitalization and ED visit charges from the Missouri Patient Abstract System (PAS).[1] We included only ED visits and hospitalizations with TBI as the primary diagnosis. PAS, which is managed by the Missouri Department of Health and Senior Services (DHSS), contains data from all of the 135 acute care hospitals in Missouri directly or through the Missouri Hospital Association. This system uses the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnostic codes to define different mechanisms and causes of TBI.[3] For this study, we combined data from 2001 through 2005 to estimate annual mean inpatient hospitalization and ED visit charges.

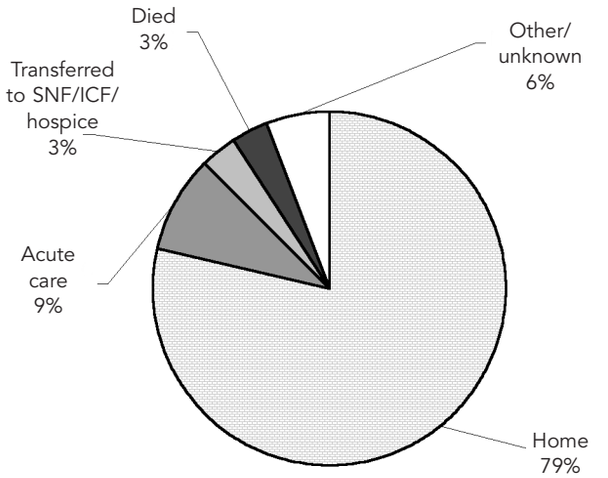
We used Missouri death certificates/records for the years 2001–2005 to obtain mortality data.[4] Death certificates use the ICD, 10th Revision (ICD-10) codes to define the different mechanisms and causes of TBI. The ICD-9-CM and ICD-10 codes used in this study are listed in Figure 3; the first set of codes classifies the cause and mechanism of injury, while the second set specifies the cause of death.[5]

Data analysis

To calculate the direct cost associated with TBI, we used hospital and ED visit charges. We expected these charges to be paid by insurance companies and/or patients. Because of market imperfection in the health-care industry, the charges do not represent the true economic cost of the products and care services.[6] A cost-to-charge ratio is used by Medicare and third-party payers to reimburse the hospitals and health-care providers. We used a cost-to-charge ratio of 0.442 for Missouri to estimate the direct cost of TBI.[7,8]

Because the study covered a five-year span, we determined that inflation would influence the direct medical charges in the medical care industry. We used the Consumer Price Index (CPI) for Medical Care for All Urban Consumers, 2001–2005, in the Midwest region (using 2001 as the base year) to adjust these annual charges for inflation.[9]

Figure 2. Dispositions of traumatic brain injury patients from hospitalizations and emergency department visits in Missouri, 2001–2005



SNF = skilled nursing facility
ICF = intermediate care facility

We computed the social cost (i.e., YPLL) and the indirect cost (i.e., lost productivity) to measure the cost of premature deaths related to TBI. We computed YPLL by counting the remaining years of expected life based on the abridged life table from the Missouri Vital Statistics. The changes in abridged life tables for the years 2001–2005 were minimal; hence, we used the 2003 (midpoint) abridged life table values to compute the YPLL.[10]

We estimated the productivity losses due to TBI-related deaths with the annual mean mortality for the years 2001–2005.[4] Because the Missouri-specific estimates of present discounted value of future earnings (PDVFE) were unavailable, we used the national estimates for 2000. This method takes into account the life expectancy for different gender and age groups, the percentage of people in the labor force or housekeeping, the current pattern of earnings at successive ages, an imputed value of household production, and the discount rate.[11] We computed the PDVFE for Missouri using a 3% discount rate by age and gender. Numbers and data by case rather than visits were not available because of the possibility of identifying individual patients. Because we sought to estimate the total burden/cost, this factor did not affect the total cost

Figure 3. ICD-9-CM codes for TBI-related ED visits and hospitalizations and ICD-10 codes for deaths

Codes for TBI-related ED visits and hospitalizations *Description*	*ICD-9-CM codes*
Fracture of the vault or base of the skull	800.0–801.9
Other and unqualified multiple fractures of the skull	803.0–804.9
Intracranial injury, including concussion, contusion, laceration, and hemorrhage	850.0–854.1
Other open wound to the head	873.0–873.9
Late effect of fracture of skull and face bones	905.0
Late effect of intracranial injury without mention of skull fracture	907.0
Head injuries unspecified	959.01
Codes for TBI-related deaths *Description*	*ICD-10 codes*
Open wound of the head	S01.0–S01.9
Fracture of skull and facial bones	S02.0, S02.1, S02.3, S02.7–S02.9
Injury to optic nerve and pathways	S04.0
Intracranial injury	S06.0–S06.9
Crushing injury of head	S07.0, S07.1, S07.8, S07.9
Other unspecified injuries of head	S09.7, S09.9
Open wounds involving head with neck	T01.0
Fractures involving head with neck	T02.0
Crushing injuries involving head with neck	T04.0
Injuries of brain and cranial nerve with injuries of nerves and spinal cord at neck level	T06.0
Sequelae of injuries of head	T90.1, T90.2, T90.4, T90.5, T90.8, T90.9

ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification

TBI = traumatic brain injury

ED = emergency department

ICD-10 = International Classification of Diseases, 10th Revision

estimates. However, the per-visit cost estimate was an underestimation of the cost per case.

The Institutional Review Board at the Missouri DHSS reviewed this study protocol and determined it to be exempt.

RESULTS

Of the four major causes of TBI, unintentional falls caused the greatest number of TBI hospitalizations and ED visits, but motor vehicle traffic accidents caused the highest mortality rate. Motor vehicle traffic accidents resulted in (*1*) the highest number of ED visits and hospitalization direct costs (followed by unintentional falls), (*2*) the highest YPLL and productivity losses, and (*3*) the youngest mean age (36) at death from TBI. Conversely, unintentional falls resulted in the oldest mean age (66) at death from TBI (Table 1).

Mortality

During 2001–2005, TBI was the underlying cause of 1,358 deaths annually in Missouri. Four major causes accounted for 89% of all TBI deaths: motor vehicle traffic crashes (39%), firearms (32%), unintentional falls (15%), and motorcycle crashes (3%). All other causes accounted for about 11% of TBI deaths. We determined the TBI death rate to be 23.8 per 100,000 Missouri population, a rate that was almost three times as high in males (35.3) as in females (12.8). Among the four major causes, motor vehicle traffic crashes led to the highest TBI-related death rate (9.2), followed by firearms (7.6), unintentional falls (3.6), and motorcycle crashes (0.6). Males had higher rates of TBI-related deaths than females at all age levels. The gender disparity in TBI-related death was highest in motorcycle crashes and lowest in unintentional falls (Table 2).

Those ≥80 years of age had the highest overall TBI mortality, as well as the highest TBI mortality from unintentional falls for both genders. Males between the ages of 20 and 29 years had the highest number of motor vehicle traffic crash-related TBI deaths, and females aged 10–19 years had the highest rates. Firearms-related TBI deaths were highest for males ≥80 years of age, and for females the highest rate was for those aged 40–49 years. Males between the ages of 20

and 29 and females aged 30–39 had the highest TBI death rates due to motorcycle crashes (Table 2).

Direct cost

During 2001–2005, there were 20,688 inpatient hospitalizations (an annual mean of 4,138 hospitalizations, or 70.8 per 100,000) and 47,428 ED visits (an annual mean of 9,486 ED visits) related to TBI in Missouri. We estimated the associated annual direct cost to be nearly $95 million in total, or $1.67 million per 100,000 population. The four major causes of TBI accounted for 68% of all direct medical costs of TBI: motor vehicle traffic crashes (33%), unintentional falls (30%), motorcycle crashes (3%), and firearms (2%). Even after adjusting for inflation, the cost of TBI ED visits and hospitalizations increased 59.4%, from $69.8 million in 2001 to $111.3 million in 2005. We estimated each Missouri resident's direct costs during 2001–2005 at $17 annually (data not shown).

YPLL

For the period 2001–2005, we determined the estimated annual YPLL due to mortality from TBI as 48,501. The four major causes of TBI caused 90% of total YPLL due to TBI mortality. Table 3 shows the estimated annual YPLL by the four major causes and the breakdown by gender. TBI from motor vehicle traffic crashes caused the highest YPLL, followed by TBI from firearms, unintentional falls, and motorcycle crashes. Males' YPLL accounted for 73% (35,238), whereas females' YPLL accounted for 27% (13,263) of the total YPLL. We estimated a mean loss of 36 YPLL per TBI-related death during 2001–2005.

Also during this period, we estimated the mean age of TBI fatality as 44 years. However, this mean age varied by cause of TBI, with people dying at a younger age (age 36) due to motor vehicle traffic crashes and an older age (66 years) due to unintentional falls. The mean age at death due to firearms was 43 years; the mean age at death due to motorcycle crashes was 39 years (Table 3).

Productivity losses

We estimated the total productivity loss due to TBI-related deaths at almost $1.1 billion annually in Missouri. We estimated the rate of productivity loss at $18.8 million per 100,000 Missouri residents ($188 per person), with a three times higher rate for males ($31.7 million) than for females ($6.5 million) (Table 4). Motor vehicle crash-related productivity loss was the highest at $513 million, followed by firearms ($383 million), unintentional falls ($38 million), and motorcycle crashes ($37 million). Table 4 also shows estimated annual productivity loss by the four major causes and by gender.

Of the total, males accounted for about 82% of the productivity loss and females accounted for 18%. We observed a similar pattern by gender by the four major causes of TBI: the rate of productivity loss due to motor vehicle crashes was $9 million per 100,000 Missouri residents, followed by firearms ($6.7 million); unintentional falls and motorcycle crashes each caused $0.7 million in productivity loss (Table 4).

DISCUSSION

Our study found that TBI imposes a heavy social and economic burden on Missouri residents, including more than 1,300 lives lost, more than $1.2 billion in direct ED visit and hospitalization costs and indirect costs due to lost productivity, and nearly 50,000 YPLL. To the best of our knowledge, this is the first study to evaluate the health and economic burden of TBI for an entire state. Our study also identified groups at high risk for TBI with respect to age, gender, and the four major causes of TBI-related deaths. This information

Table 1. Summary statistics for TBI by major causes in Missouri, 2001–2005

		Four major causes of TBI deaths			
Variable	*All causes*	*Motor vehicle traffic crashes*	*Firearms*	*Unintentional falls*	*Motorcycle crashes*
TBI rate	238.6	56.1	1.9	87.6	3.1
Mortality rate per 100,000	23.8	9.2	7.6	3.6	0.6
Direct cost, in millions of dollars	$94.70	$31.67	$1.91	$28.19	$2.39
Total years of potential life lost (rate[a])	48,501 (850)	23,187 (406)	15,770 (276)	2,985 (52)	1,445 (25)
Total productivity losses in millions of dollars (rate[a])	$1,071 ($18.75)	$513 ($8.98)	$383 ($6.70)	$37 ($0.65)	$38 ($0.66)
Mean age at death (in years)	44	36	43	66	39

[a]Rate per 100,000 population

TBI = traumatic brain injury

Table 2. Annual rate[a] of deaths resulting from TBI by age and cause: Missouri, 2001–2005

				Four major causes of TBI deaths											
	All causes			*Motor vehicle traffic crashes*			*Firearms*			*Unintentional falls*			*Motorcycle crashes*		
Age group (in years)	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*
Missouri	23.8	35.3	12.8	9.2	12.6	6.0	7.6	13.5	2.0	3.6	4.1	3.1	0.6	1.2	0.1
<10	4.5	4.8	4.3	2.4	2.2	2.6	0.3	0.5	0.2	0.1	0.1	0.1	0.0	0.1	0.0
10–19	19.1	27.0	10.9	13.4	17.5	9.0	4.6	7.9	1.1	0.1	0.1	0.1	0.3	0.6	0.0
20–29	30.1	48.7	11.6	15.6	22.9	8.2	11.1	20.1	2.1	0.5	0.8	0.1	0.9	1.9	0.0
30–39	22.8	34.9	10.9	10.0	13.9	6.2	8.9	14.9	2.9	0.6	1.1	0.2	1.1	1.7	0.5
40–49	23.0	34.6	11.8	8.4	10.9	6.0	9.2	14.9	3.6	1.3	2.2	0.5	1.0	1.8	0.3
50–59	21.2	35.3	7.8	6.6	9.4	4.0	8.8	15.9	2.1	2.2	3.6	0.9	0.8	1.6	0.1
60–69	23.9	35.9	13.2	6.9	7.9	6.0	8.5	15.9	1.9	4.7	6.1	3.4	0.4	0.7	0.1
70–79	39.4	65.2	19.6	8.3	11.8	5.6	11.0	23.5	1.6	13.7	19.4	9.4	0.2	0.4	0.0
≥80	76.0	122.4	53.3	9.7	18.3	5.4	10.0	28.0	1.2	45.0	59.4	38.0	0.1	0.3	0.0
Deaths by gender (percent)	100	72	28	100	67	33	100	87	13	100	56	44	100	89	11
All causes (percent)	100	100	100	39	36	47	32	38	15	15	12	24	3	3	1

[a]Rate per 100,000 population

TBI = traumatic brain injury

Table 3. Annual rate[a] of YPLL due to mortality resulting from TBI, by age and cause: Missouri, 2001–2005[b]

				Four major causes of TBI deaths											
	All causes			*Motor vehicle traffic crashes*			*Firearms*			*Unintentional falls*			*Motorcycle crashes*		
Age group (in years)	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*
Missouri	850	1,268	453	406	545	275	276	484	79	52	68	38	25	46	5
<10	338	343	332	178	155	203	25	33	16	8	7	8	2	4	0
10–19	1,183	1,630	713	830	1.059	589	278	475	70	6	9	3	19	37	0
20–29	1,629	2,589	671	852	1,228	477	590	1,061	120	25	43	6	50	100	0
30–39	1,012	1,512	516	449	605	295	389	645	135	28	47	10	49	74	24
40–49	818	1,190	456	304	377	232	323	515	137	47	75	20	36	63	10
50–59	566	922	232	179	244	118	234	416	64	60	95	27	22	41	3
60–69	449	646	274	134	144	126	156	286	40	88	219	69	8	14	2
70–79	470	746	261	101	134	75	130	273	21	166	219	125	2	5	0
≥80	526	808	387	70	123	44	68	189	9	310	387	273	1	2	0
Percent of YPLL by gender	100	73	27	100	65	35	100	85	15	100	63	37	100	89	11
Percent of all causes	100	100	100	48	43	61	33	38	17	6	5	8	3	4	1
Percent of YPLL per person	36	36	35	44	43	46	36	36	41	15	17	12	40	40	41
Mean age at death (in years)	44	43	47	36	35	37	43	43	43	66	63	70	39	39	42

[a]Rate per 100,000 population

[b]We used the Abridged Life Table for Missouri for 2003 to compute mean number of years of life remaining.

YPLL = years of potential life lost

TBI = traumatic brain injury

Table 4. Annual rate[a] of productivity losses (in millions of dollars) due to TBI-related deaths by age, gender, and major cause: Missouri, 2001–2005[b]

				Four major causes of TBI deaths											
	All causes			*Motor vehicle traffic crashes*			*Firearms*			*Unintentional falls*			*Motorcycle crashes*		
Age group (in years)	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*	*All*	*Male*	*Female*
Missouri	18.8	31.7	6.5	9.0	14.0	4.2	6.7	12.5	1.2	0.7	1.1	0.2	0.7	1.3	0.1
<10	4.5	5.3	3.6	2.3	2.5	2.2	0.4	0.5	0.2	0.1	0.1	0.1	0.0	0.1	0.0
10–19	25.1	38.4	11.2	17.3	24.9	9.4	6.3	11.3	1.1	0.1	0.2	0.1	0.5	0.9	0.0
20–29	43.0	73.7	12.4	21.8	34.7	8.8	16.3	30.4	2.2	0.7	1.3	0.1	1.4	2.8	0.0
30–39	28.2	46.9	9.6	12.1	18.8	5.5	11.2	20.0	2.5	0.8	1.5	0.2	1.4	2.3	0.5
40–49	20.8	34.5	7.5	7.4	11.0	3.8	8.5	15.0	2.2	1.2	2.2	0.3	1.0	1.8	0.2
50–59	11.0	20.0	2.6	3.2	5.2	1.3	4.8	9.1	0.7	1.2	2.1	0.3	0.5	0.9	0.0
60–69	3.7	6.4	1.2	1.0	1.5	0.6	1.4	2.9	0.2	0.7	1.1	0.3	0.1	0.2	0.0
70–79	1.3	2.6	0.3	0.3	0.5	0.1	0.4	1.0	0.0	0.4	0.7	0.2	0.0	0.0	0.0
≥80	0.3	0.8	0.1	0.1	0.1	0.0	0.1	0.2	0.0	0.2	0.4	0.1	0.0	0.0	0.0
Percent of productivity losses by gender	100	82	18	100	76	24	100	90	10	100	85	15	100	93	7
Percent of all causes	100	100	100	48	44	65	36	39	19	3	4	3	4	4	1

[a]Rate per 100,000 population

[b]We used the present discounted value of future earnings by age and gender at a 3% discount rate to calculate the productivity losses from TBI. See: Missouri Department of Health and Senior Services. Missouri information for community assessment: death MICA, 2001–2004 [cited 2005 Dec 1]. Available from: URL: http://www.dhss.mo.gov/DeathMICA/index.html

TBI = traumatic brain injury

is useful to public health authorities for directing resources to prevent the major causes of TBI that result in high human and financial losses.

During 2001–2005, in terms of the level of severity, moderately serious TBI accounted for 56% of the total injuries, followed by the most serious injuries (40%) and the least serious injuries (3%). We determined a mean of 36 YPLL per person due to TBI and $188 annually in productivity losses per person.

During this period, unintentional falls were the most common cause of TBI (37%), followed by motor vehicle traffic crashes (26%), and struck by/against a person or object (21%). Nationally, the top three causes of TBI followed suit: falls (28%), motor vehicle traffic crashes (20%), and struck by/against a person or object (19%).[5] Another study estimated the same top two causes of TBI nationally: falls (41%) and motor vehicle traffic crashes (39%).[12] A study in England found the same two causes of TBI: unintentional falls (50%) and road traffic collisions (33%).[13]

Like the studies at the national level, our study observed an interesting scenario: though the unintentional falls-related TBI were highest among the youngest and oldest Missourians (those aged 0–5 and those aged ≥80 years), the rate of mortality was highest only for people aged ≥80 years.[5,14]

The adoption of Brain Trauma Foundation (BTF) guidelines for treating severe TBI has been shown to result in substantial savings in costs and lives.[15] One study concluded that adhering to the BTF treatment protocol could attain a significant reduction in length of hospital stay and charges for TBI.[16] According to this study, compliance with the TBI protocol saved $4.7 million in hospital charges during the period of six years. While existing studies add to the knowledge base of TBI, our study provided the socioeconomic cost of TBI at the state level.

Limitations

Our study had some limitations. First, we underestimated the ED visit and hospitalization costs due to an underestimation of TBI incidence, as some TBI incidents were not reported. Second, data on TBI-related disability, lost wages, quality of life, and other costs (e.g., prescriptions, transportation for care, and care wait time) were unavailable in Missouri.

CONCLUSIONS

This study found that the indirect costs were higher than the direct costs for TBI-related deaths, which is confirmed in the literature.[17] However, the losses related to TBI (e.g., in terms of deaths, as well as adverse health, social, and financial costs) are easily preventable. Prevention measures such as safety belt and helmet use, and drinking and driving laws, have proved to be effective strategies in reducing injury severity and fatalities, and they can be implemented at a very low cost.[18] These policies can play a significant role in preventing and mitigating brain injuries. Through partnering with other agencies and interested parties; working collaboratively at the federal, state, and local levels; remaining vigilant in comprehensive prevention efforts; and maintaining safety policies, we can reduce the number of TBI fatalities and injuries and the overall associated costs. In addition, states' surveillance systems can play an important role in identifying causes and risk factors for developing interventions.[19]

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