

Estimating the global incidence of traumatic brain injury

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OBJECTIVE Traumatic brain injury (TBI)—the “silent epidemic”—contributes to worldwide death and disability more than any other traumatic insult. Yet, TBI incidence and distribution across regions and socioeconomic divides remain unknown. In an effort to promote advocacy, understanding, and targeted intervention, the authors sought to quantify the case burden of TBI across World Health Organization (WHO) regions and World Bank (WB) income groups.

METHODS Open-source epidemiological data on road traffic injuries (RTIs) were used to model the incidence of TBI using literature-derived ratios. First, a systematic review on the proportion of RTIs resulting in TBI was conducted, and a meta-analysis of study-derived proportions was performed. Next, a separate systematic review identified primary source studies describing mechanisms of injury contributing to TBI, and an additional meta-analysis yielded a proportion of TBI that is secondary to the mechanism of RTI. Then, the incidence of RTI as published by the Global Burden of Disease Study 2015 was applied to these two ratios to generate the incidence and estimated case volume of TBI for each WHO region and WB income group.

RESULTS Relevant articles and registries were identified via systematic review; study quality was higher in the high-income countries (HICs) than in the low- and middle-income countries (LMICs). Sixty-nine million (95% CI 64–74 million) individuals worldwide are estimated to sustain a TBI each year. The proportion of TBIs resulting from road traffic collisions was greatest in Africa and Southeast Asia (both 56%) and lowest in North America (25%). The incidence of RTI was similar in Southeast Asia (1.5% of the population per year) and Europe (1.2%). The overall incidence of TBI per 100,000 people was greatest in North America (1299 cases, 95% CI 650–1947) and Europe (1012 cases, 95% CI 911–1113) and least in Africa (801 cases, 95% CI 732–871) and the Eastern Mediterranean (897 cases, 95% CI 771–1023). The LMICs experience nearly 3 times more cases of TBI proportionally than HICs.

CONCLUSIONS Sixty-nine million (95% CI 64–74 million) individuals are estimated to suffer TBI from all causes each year, with the Southeast Asian and Western Pacific regions experiencing the greatest overall burden of disease. Head injury following road traffic collision is more common in LMICs, and the proportion of TBIs secondary to road traffic col-

ABBREVIATIONS AFR = African Region; AMR-L = Region of the Americas–Latin America; AMR-US/Can = Region of the Americas–United States and Canada; EMR = Eastern Mediterranean Region; EUR = European Region; GBD = Global Burden of Disease; GBD 2015 = GBD Study 2015; HI = head injury; HIC = high-income country; IHME = Institute for Health Metrics and Evaluation; LIC = low-income country; LMICs = low- and middle-income countries; MIC = middle-income country; MOI = mechanism of injury; P(RTI) = probability that a member of the population will sustain an RTI annually; P(RTI|TBI) = probability that TBI is secondary to RTI; P(TBI|RTI) = probability that an RTI will lead to a TBI; PRISMA = Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RTI = road traffic injury; RTI_{TOTAL} = total number of RTIs in a country annually; RTI∩TBI = intersection of RTI_{TOTAL} and TBI_{TOTAL}; SEAR = Southeast Asian Region; TBI = traumatic brain injury; TBI_{TOTAL} = total number of TBI cases in a region annually; WB = World Bank; WHO = World Health Organization; WPR = Western Pacific region; ∩ = intersection of 2 events; | = conditional on 1 event.

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lision is likewise greatest in these countries. Meanwhile, the estimated incidence of TBI is highest in regions with higher-quality data, specifically in North America and Europe.

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KEYWORDS epidemiology; global; incidence; prevalence; traumatic brain injury; volume; worldwide

TRAUMATIC brain injury (TBI), often referred to as the “silent epidemic,”^{208,253} remains a growing public health concern and represents the greatest contributor to death and disability globally among all trauma-related injuries.²⁰⁶ Previous studies from the United States and New Zealand have estimated approximately 500–800 new cases of TBI per 100,000 people each year.^{83,209} However, estimates of the TBI burden from low- and middle-income countries (LMICs) are scarce. A large survey-based study in 8 LMICs identified a lifetime prevalence of TBI from < 1% (China) to nearly 15% (Mexico and Venezuela) of the studied population, with most estimates approximating those from high-income countries (HICs).¹³⁴ Efforts to identify reliable epidemiological data on the incidence of and the disability and mortality from TBI in resource-poor settings are still needed.

Road traffic collisions are a significant source of TBI.^{24,161,216,231,257,259} Using national registries, population-based literature, and statistical modeling, the Global Burden of Disease (GBD) Study 2015 (GBD 2015)¹¹⁶ estimated the incidence of road traffic injuries (RTIs) in countries worldwide. By understanding the relationship between RTI and TBI, the incidence of TBI can be estimated. Because the interaction between RTI and TBI probably differs across regions of various populations, regulations, and infrastructures, a region-specific estimate of this relationship is essential to ensure accurate TBI estimates.

Beyond a fundamental disparity in quality data, a majority of the global population resides in LMICs, underscoring the need for reliable estimates of the TBI burden in resource-poor settings. In this comprehensive review, we provide estimates for TBI across geographic regions and income groups to deliver a global estimate of the volume and burden of TBI worldwide.

Methods

Overview

Incidence figures and overall disease volume were calculated from literature reviews, national registries, the GBD initiative, and the World Bank (WB). A similar methodology of estimating the frequency of traumatic injuries in LMICs has been described elsewhere.^{4,149} A flow-chart illustrates the contribution of relevant data sources and a stepwise progression in our methodology (Fig. 1). Initially, the incidences of RTI in different countries were obtained from the Institute for Health Metrics and Evaluation (IHME) GBD dataset. The incidences of RTIs were converted to population-based rates, that is, P(RTI), which represents the proportion of RTIs in a given population (that is, the probability that a person living in a country will sustain an RTI in a year; Fig. 1 II). By multiplying P(RTI) by the country population, we were able to obtain the RTI_{TOTAL}, representing the total number of RTIs in a country annually (Fig. 1 III):

$$RTI_{TOTAL} = P(RTI) \times Population.$$

We next sought to obtain the number of patients who had sustained a TBI or head injury (HI) from total RTIs, represented by RTI∩TBI (that is, the intersection of RTI_{TOTAL} and TBI_{TOTAL}; Fig. 1). To this end, we conducted a systematic review and meta-analysis of studies reporting the proportion of RTIs that had resulted in TBIs in different WHO regions and income groups. This proportion is expressed as a probability value, P(TBI|RTI), that is, the proportion sustaining TBI after RTI (Fig. 1 IV):

$$P(TBI|RTI) = \frac{RTI \cap TBI}{RTI_{TOTAL}}$$

By multiplying the RTI_{TOTAL} by P(TBI|RTI), we obtained the total number of patients who sustained TBI after RTI (Fig. 1 V):

$$RTI \cap TBI = RTI_{TOTAL} \times P(TBI|RTI)$$

$$RTI \cap TBI = RTI_{TOTAL} \times \frac{RTI \cap TBI}{RTI_{TOTAL}}$$

Understanding that traffic collisions are one of many TBI mechanisms of injury (MOIs), we sought the proportion of TBIs that are caused by RTIs. Accordingly, we conducted another systematic review and meta-analysis, this time to quantify the proportion of TBIs with RTI as the MOI in different WHO regions and income groups. This proportion is expressed as a probability value, P(RTI|TBI), that is, the proportion of TBIs secondary to RTIs (Fig. 1 VI):

$$P(RTI|TBI) = \frac{RTI \cap TBI}{TBI_{TOTAL}}$$

Multiplying RTI∩TBI by the inverse of P(RTI|TBI) and thereby accounting for the non-RTI causes of TBI, we obtained the total number of TBI cases annually in different WHO regions and income groups (Fig. 1 VIII):

$$TBI_{TOTAL} = \frac{RTI \cap TBI}{P(RTI|TBI)}$$

$$TBI_{TOTAL} = \frac{RTI \cap TBI}{\frac{RTI \cap TBI}{TBI_{TOTAL}}}$$

$$TBI_{TOTAL} = RTI \cap TBI \times \frac{TBI_{TOTAL}}{RTI \cap TBI}$$

A more detailed explanation of our methodology is outlined below.

Incidence of RTIs

To identify the proportion of the population that sus-

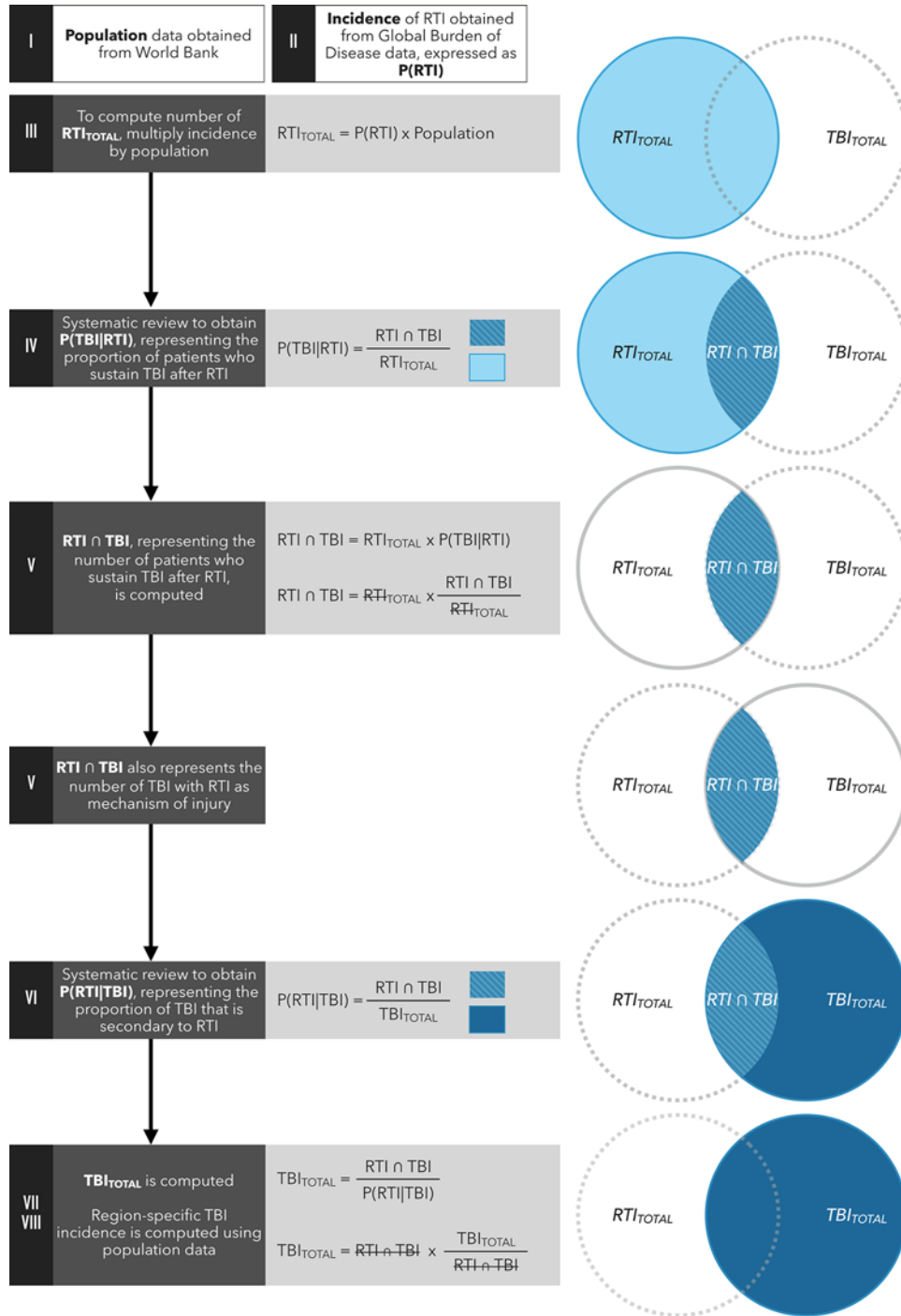


FIG. 1. Methodology flow diagram. $P(RTI)$ = probability that a member of the population will sustain an RTI annually; $P(TBI|RTI)$ = probability that a TBI is secondary to an RTI; $P(RTI|TBI)$ = probability that an RTI will lead to TBI; RTI_{TOTAL} = total cases of RTI, with or without TBI; $RTI \cap TBI$ = intersection of RTIs and TBIs, thus representing either the number of RTIs that lead to TBI or the number of TBIs secondary to RTIs; TBI_{TOTAL} = total cases of TBI, whether the mechanism is an RTI or a non-RTI. Figure is available in color online only.

tains an RTI every year, we obtained and extracted relevant data on the incidence of RTI from the IHME GBD dataset by using the open-access site vizhub.healthdata.org/epi.¹¹⁶ Region-specific data sources included the World Health Organization (WHO) regional office, ministries of health, and so forth, while mixed-effects-modeled

IHME GBD data were excluded. Regions not recognized by the WB or the WHO were excluded (for example, Tibet). In a few instances, the incidence for only one sex was provided; therefore, to maintain uniformity and generalizability, incidence data that included male and female sex were selected for analysis over incidence data for just one

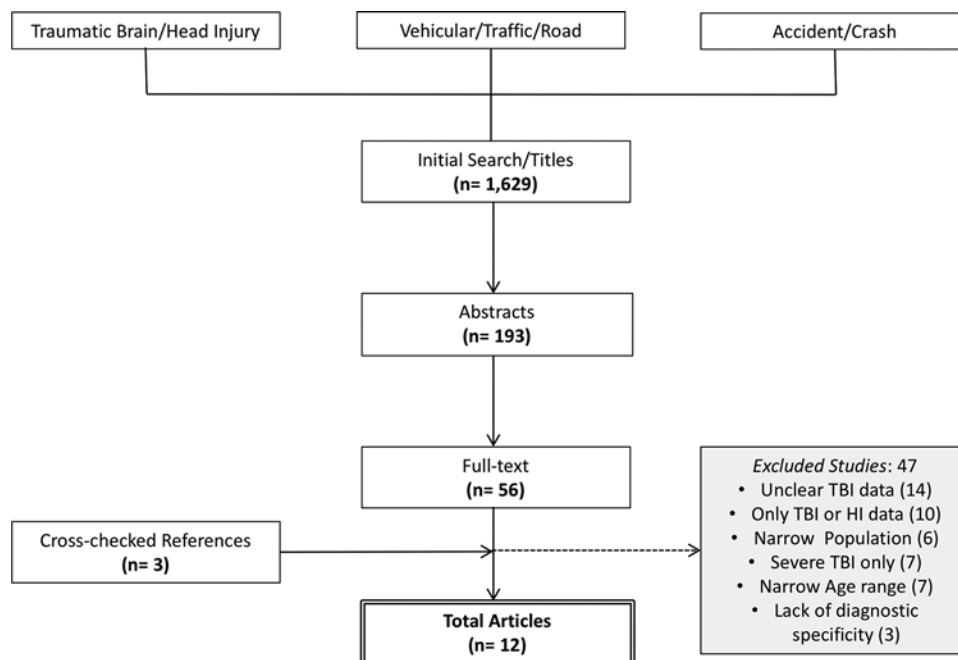


FIG. 2. PRISMA diagram for P(TBI|RTI): quantifying the proportion of RTIs that include TBI.

sex. Incremental age and sex values were averaged, and mean incidence values were estimated for each country. Each incidence value was expressed as the probability that a person living in a country would sustain an RTI annually [P(RTI); Fig. 1 II and III].

The total number of RTIs (RTI_{TOTAL}) per WHO region and WB income group was calculated as the product of the WB 2015 population metadata²⁶⁰ and the GBD RTI data. The WB metadata are modeled figures to project population changes over time.

Proportion of RTIs Causing TBIs

The probability of sustaining a TBI after an RTI is represented by P(TBI|RTI). This is equal to the ratio of RTIs with TBI to all RTI cases with or without TBI in a population (Fig. 1 IV). To identify this proportion, a systematic literature search of PubMed was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for studies reporting the proportion of RTIs resulting in TBI or HI (Fig. 2).¹⁷³ The aim of the search was to comprehensively identify population- and hospital-based studies quantifying the injuries resulting from traffic accidents. Thus, a series of searches were performed to capture a wide range of relevant studies to calculate the proportion of TBIs or HIs resulting from the primary event of an RTI. A full description of search parameters, as well as inclusion and exclusion criteria, can be found in the *Appendix*. Briefly, search terms included “traffic accident,” “vehicular crash,” “vehic* accident,” “brain injury,” and “head injury.” Our search focused on “accident” as opposed to “crash” or “collision” because most epidemiological studies on road injuries have historically followed this notation convention until recently, when studies began to shift to more objective terminology. Thus, our use of “vehicular

crash” was an attempt to capture more recent studies using this new convention. Articles were included if epidemiological data categorized the types of injuries sustained from RTIs and if the proportion of RTIs resulting in HI or brain injury was discernible. Studies that included only TBI or HI and those that only reported a certain severity of injury (for example, severe TBI only) were excluded to minimize selection bias. Two reviewers (A.R., S.G.) and a single arbiter (M.C.D.) conducted this search.

Next, we conducted a search of governmental traffic injury registries that reported HIs. The Organisation for Economic Co-operation and Development (OECD) Health Statistics report (“Injuries in Road Traffic Accidents 2016”) and citation information from the IHME GBD data on road injury incidence were queried.¹¹⁶ Registries from 15 different countries were screened: United States, United Kingdom, Canada, Mexico, Brazil, Australia, New Zealand, Taiwan, China, India, South Africa, Belgium, Chile, France, Italy. A single registry (United Kingdom) yielded compatible information on HI and was incorporated into the model with the peer-reviewed study data.

Study results were then pooled using MedCalc software version 15.1 to conduct a meta-analysis. Data were pooled with inverse probability random-effects weighting to estimate the proportion of RTIs resulting in TBI, represented by P(TBI|RTI) for each WB income group and WHO region.

The number of cases of RTI that resulted in TBI, represented by $RTI \cap TBI$, was calculated as the product of RTI_{TOTAL} and P(TBI|RTI) for all WHO regions and WB income groups (Fig. 1 V).

Traumatic Brain Injury MOI

Another systematic literature review and meta-analysis

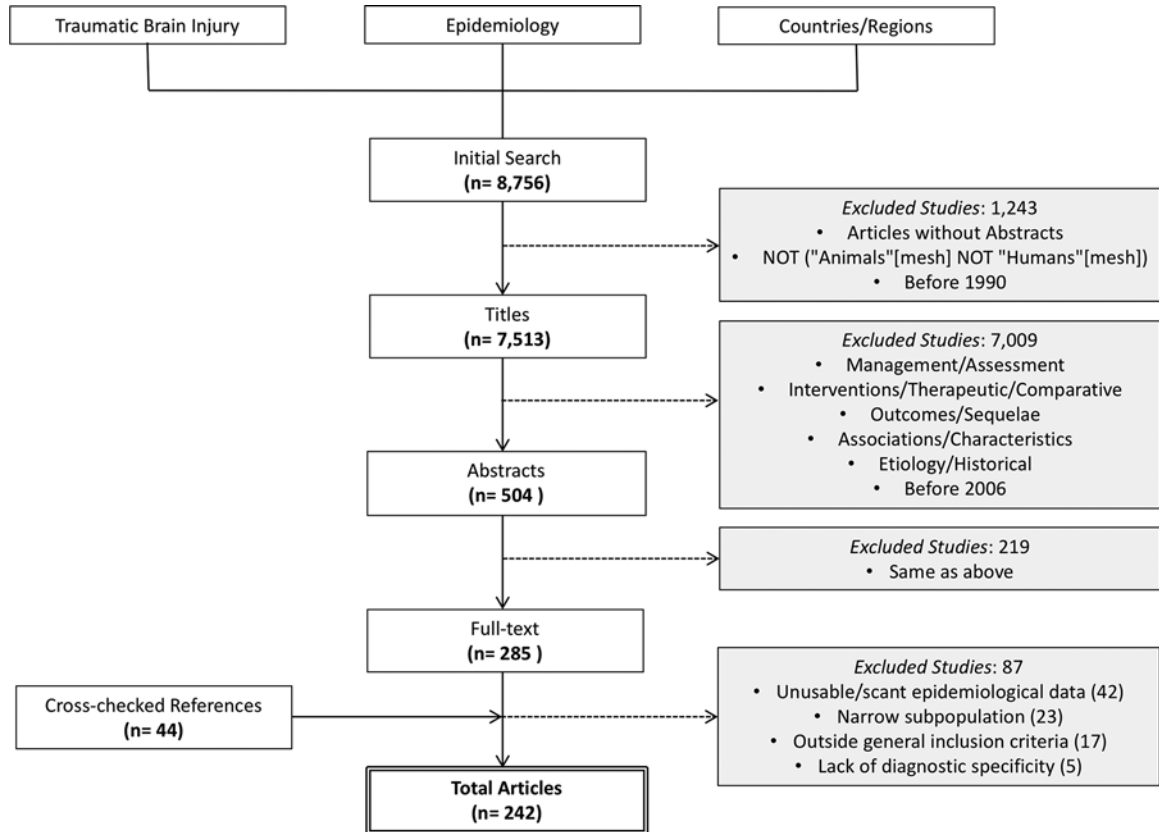


FIG. 3. PRISMA diagram for MOIs: quantifying the proportion of TBIs secondary to RTIs [P(RTI|TBI)].

was conducted to estimate the relative distribution and proportions of MOI for TBI. The goal was to calculate the proportion of TBI cases that were attributable to RTI, represented by $P(RTI|TBI)$, or the probability that TBI resulted from RTI as a mechanism. This is equal to the ratio of TBI caused by RTI to TBI from all causes in a population (Fig. 1 VI).

Following the PRISMA guidelines,¹⁷³ we searched the PubMed and Cochrane Database of Systematic Reviews to identify studies reporting country-specific epidemiological data on TBI MOI. A full list of search terms and the search methodology can be found in the *Appendix*, and a detailed breakdown of the article screening process is illustrated in Fig. 3. In summary, MeSH and title/abstract terms were included to maximize the inclusion of studies related to TBI epidemiology (incidence, prevalence, burden, mortality, and so forth) published in countries recognized by the WB. Given the scope of this review, 4 reviewers (A.R., M.P., R.E.B., Y.C.H.) and 1 arbiter (M.C.D.) screened the articles, while 5 investigators extracted relevant data from source articles (A.R., R.E.B., M.P., Y.C.H., M.C.D.). The methodological quality of individual studies was scored on a 6-point scale from lowest (0 = small sample size, hospital based) to highest (5 = large, ideal population based) to allow quality comparisons among regions and income groups.²³⁸ As described by Feigin et al.,⁸² less rigorous study quality was permitted for studies from LMICs, from which data would otherwise be unavailable.

Mechanism of injury studies were first selected based on completeness of data (that is, the sum of individual MOI cases equaled the total number of TBI cases reported). Studies were then reviewed for study design and subject selection; studies reporting incidence within a population that could be extended beyond a hospital (that is, at least the regional level) were included for data analysis. Mechanism of injury studies were excluded if they had narrow selection criteria (only pediatric patients, only severe TBI, and so forth).

Incidence of TBIs

The total number of TBI cases from all MOIs (TBI_{TOTAL}) in a population annually was computed by dividing the number of TBI cases secondary to RTI ($RTI \cap TBI$) by the proportion of TBIs caused by RTIs [$P(RTI|TBI)$; Fig. 1 VII]. The WB population data and TBI_{TOTAL} were then used to calculate the incidence of TBI in a given population [$P(TBI)$; Fig. 1 VIII]. The calculations for confidence intervals are outlined in the Supplement.

Severity of Injury

Finally, we sought to characterize the distribution of mild, moderate, and severe TBI. Studies identified in the systematic review for MOI (*Methods, Traumatic Brain Injury MOI*) were queried for the reporting of TBI severity. Population-based studies categorizing TBI severity with Glasgow Coma Scale scores of mild (13–15), moderate

TABLE 1. Proportion, incidence, and volume of TBI worldwide by WB income group and WHO region

Group	I		II		III		IV		V		VI		VII		VIII	
	Population	P(RTI)	RTI _{TOTAL}	P(TBI RTI)	RTI∩TBI	P(RTI TBI)	TBI _{TOTAL}	95% CI	TBI Incidence (cases per 100,000 people)	95% CI						
LMIC	6,160,384,080	0.01308	80,577,165	0.344	27,727,408	0.555	49,954,794	30,597,109–69,312,478	811	497–1125						
HIC	1,188,267,169	0.01300	15,448,795	0.289	4,464,702	0.249	17,903,925	8,963,471–26,844,378	1507	754–2259						
AFR	990,267,592	0.01292	12,798,416	0.344	4,404,063	0.555	7,934,534	7,247,018–8,622,050	801	732–871						
AMR-L	634,315,984	0.01368	8,677,844	0.335	2,906,427	0.504	5,765,538	4,840,302–6,690,774	909	763–1055						
AMR-US/Can	357,270,594	0.01121	4,004,087	0.289	1,157,181	0.249	4,640,418	2,323,192–6,957,645	1299	650–1947						
EMR	648,060,427	0.01300	8,425,138	0.330	2,783,097	0.479	5,814,715	4,999,254–6,630,175	897	771–1023						
EUR	916,755,857	0.01201	11,007,015	0.310	3,416,926	0.368	9,278,934	8,354,033–10,203,834	1012	911–1113						
SEAR	1,928,530,522	0.01529	29,484,574	0.344	10,145,937	0.555	18,279,321	15,387,571–21,171,070	948	798–1098						
WPR	1,873,450,273	0.01405	26,331,186	0.336	8,853,523	0.511	17,312,953	14,746,696–19,879,210	924	787–1061						
Global	7,348,651,249						69,026,412	64,213,245–73,839,580	939	874–1005						

AFR = African Region; AMR-L = Region of the Americas–Latin America; AMR-US/Can = Region of the Americas–United States and Canada; EMR = Eastern Mediterranean Region; EUR = European Region; HIC = high-income country; LMICs = low- and middle-income countries; P(RTI) = probability that a member of the population will sustain an RTI annually; P(RTI|TBI) = probability that TBI is secondary to RTI; P(TBI|RTI) = probability that RTI will lead to TBI; RTI = road traffic injury; RTI_{TOTAL} = total cases of RTI, with or without TBI; RTI∩TBI = intersection of RTIs and TBIs, thus representing either the number of RTIs that lead to TBI or the number of TBIs with RTI as the mechanism of injury; SEAR = Southeast Asia Region; TBI = traumatic brain injury; TBI_{TOTAL} = total cases of TBI, whether mechanism is RTI or non-RTI; WPR = Western Pacific Region.

(9–12), and severe (3–8) were extracted. Severity distribution values were pooled using random-effects inverse weighting meta-analysis in accordance with the methodology and reasoning outlined above (*Methods, Proportion of RTIs Causing TBIs*). From these data, the proportion of different TBI severities was calculated and multiplied by the total TBI incidence to arrive at an estimated incidence of mild, moderate, and severe TBI across geographic regions and income brackets.

Results

Incidence of RTIs

A total of 66 countries were represented in the GBD RTI mean incidence rate data, including all 7 WHO regions—African Region (AFR) = 20 countries, Region of the Americas–Latin America (AMR-L) = 6 countries, Region of the Americas–United States and Canada (AMR-US/Can) = 1 country, Eastern Mediterranean Region (EMR) = 8 countries, European Region (EUR) = 18 countries, Southeast Asian Region (SEAR) = 6 countries, Western Pacific Region (WPR) = 7 countries—and all WB income groups (high = 16, middle = 40, low = 10). The annual incidence is displayed as a proportion of the population [P(RTI)] and was highest in the SEAR (1.5%) and lowest in the AMR-US/Can (1.1%; Table 1). Despite differences in the proportion of motor vehicle users across WHO regions, there was relatively minimal variability in the risk of RTI.

Proportion of RTIs Resulting in TBI

A total of 12 large RTI studies reporting data on the proportion of HIs or TBIs were identified.^{9,29,36,46,65,103,149,170,203,216,229,249} Five WHO regions were represented: AFR = 5 studies (4 countries), AMR-L = 0 studies, AMR-US/Can = 1 study, EMR = 0 studies, EUR = 2 studies (2 countries), SEAR = 2 studies (1 country), WPR = 2 studies (2 countries). All income groups were also represented (studies: HIC = 3, middle-income country [MIC] = 6, low-income country [LIC] = 3). Methodology, sample size, and cohort characteristics for each study can be found in Supplemental Table S1. The pooled proportion of RTIs and TBIs for each region and income group is listed in Table 1. The greatest P(TBI|RTI) was found in the AFR and SEAR (34%), whereas AMR-US/Can (29%) had the lowest proportion. This equated to 4,404,063 TBI cases related to RTI in AFR and 1,157,181 in AMR-US/Can. Despite having an equivalent or lower P(TBI|RTI) than in the AFR, the SEAR and WPR carry the greatest absolute caseload of TBIs secondary to RTIs, at 10.1 and 8.9 million new cases each year, respectively.

Traumatic Brain Injury MOI and Injury Severity

The systematic review to describe TBI epidemiology and to quantify TBI MOI yielded more than 240 full-text articles from an initial 8756 titles.^{1–3,5–8,10–23,25–28,30–35,37,38,40–44,47–64,67,69–78,83,85–99,101,102,104,106–115,117–148,150–169,171,172,174–194,196–202,204,205,207,209–215,217–219,221–228,230–237,239–248,250–252,255–258,261–267} The search process is illustrated in detail in Fig. 3, while the full account of included articles with relevant epidemiological data is listed in Supplemental Table S2. Beyond epidemiological data, the brain injury character-

TABLE 2. Characteristics and overview of TBI severity studies

Parameter	Country	WHO Region	Income Level	Sample Size (no.)	Severity Index	Severity (% injuries)		
						Mild	Moderate	Severe
Authors & Year								
Selassie et al., 2014	US	AMR-US/Can	High	33,695	AIS	45.7	19.63	34.67
Bener et al., 2011	Qatar	EMR	High	1,952	GCS	82.94	9.528	7.53
Siman-Tov et al., 2016	Israel	EUR	High	2,419	GCS	72.59	9.384	18.02
Szarpak & Madziła, 2011	Poland	EUR	High	1,031	GCS	82.44	10.18	7.37
Ji et al., 2015	China	WPR	Middle	195,189	Other	78.87	18.51	2.62
Chiu et al., 2007	Taiwan	WPR	Middle	1,474	GCS	82.7	8.82	8.48
Chiu et al., 2007	Taiwan	WPR	Middle	5,754	GCS	87.46	5.89	6.64
Overall estimate				241,514		81.02	11.04	7.95

AIS = Abbreviated Injury Scale; GCS = Glasgow Coma Scale.

istics, patient demographics, and study setting and design were captured in a comprehensive database of the most relevant TBI studies worldwide over the last decade. After further filtering by study population, injury setting, completeness of data, and broad/representative subject selection, we identified 10 studies reporting on 11 unique cohorts (1 study⁵² counted twice) that provided representative TBI mechanism distributions (Supplemental Table S3).^{18,33,52,112,114,129,144,185,187,252} Five WHO regions (unique cohorts: AFR = 3, AMR-US/Can = 1, EMR = 2, EUR = 2, WPR = 3) and 2 WB income groups (HIC = 4, MIC = 7) were represented. The pooled proportion [P(RTI|TBI)] for each income group and WHO region is listed in Table 1. The P(RTI|TBI) was lowest in the AMR-US/Can (25%) and highest in the SEAR and AFR (56% each).

A total of 6 studies, comprising 7 distinct cohorts, were incorporated into the severity of injury estimate (4 WHO regions).^{33,52,125,218,228,240} Mild TBI accounted for 81.02% of injuries, moderate TBI for 11.04%, and severe TBI for 7.95% (Table 2).

Worldwide Incidence and Volume of TBI

The incidence of TBI was highest in the AMR-US/Can (1299 cases per 100,000 people, 95% CI 650–1947) and EUR (1012 cases per 100,000 people, 95% CI 911–1113) and lowest in the AFR (801 cases per 100,000 people, 95% CI 732–871; Table 1). Extrapolating onto regional populations, the greatest volume of TBI annually was observed in the SEAR (18.3 million) and WPR (17.3 million; Fig. 4).

The global incidence of all-cause, all-severity TBI is estimated at 939 cases per 100,000 people (95% CI 874–1005); thus, an estimated 69.0 million (95% CI 64.2–73.8 million) people worldwide will suffer TBI each year (Table 1). Mild TBI affects approximately 740 cases per 100,000 people, or a total of 55.9 million people each year, whereas 5.48 million people are estimated to suffer severe TBI each year (73 cases per 100,000 people).

Discussion

In this report, we have amassed a comprehensive overview of global TBI, with a focus on quantifying injury incidence and volume. Our model estimates that between 64 and 74 million new cases of TBI will occur worldwide

each year. While the incidence of TBI was highest in the AMR-US/Can and EUR, the greatest overall burden of TBI is seen in the SEAR and WPR.

Estimates provided here are generally higher than those in previous efforts to quantify the volume of TBI. In 2010, it was estimated that 1.7 million people in the United States sustain a TBI each year,⁴⁵ far fewer than our estimate of 4.6 million in the United States and Canada. However, the former report primarily examined individuals presenting to an emergency department for care and thus probably underestimated the overall population burden of TBI. Indeed, many patients who sustain a mild TBI (sports concussions, falls, low-velocity RTI) probably never seek medical attention. Zhang et al. estimated that up to 1650 adolescents per 100,000 patients suffer a concussion each year—a figure that does not include the many other types and severities of HI.²⁶⁴ Preliminary results from the 2010 GBD Project³⁹ suggested that the global incidence rate of TBI was 200 cases per 100,000 people per year, equating to approximately 15 million persons affected. For comparison, an estimated 3.8 million new cases of human immunodeficiency virus, 287 million cases of malaria, and 8.8 million cases of tuberculosis will develop each year.¹¹⁶ In terms of other common conditions causing neurological morbidity and mortality, recent estimates suggest that each year there are 16.9 million new cases of stroke and 30 million new cases of central nervous system infection.⁸² Contextualizing their figure of 15 million new cases, the GBD Project authors acknowledged the uncertainty of their estimate and that it was “a likely underestimate” because they had used hospital- and emergency department-based studies. The updated GBD study (GBD 2015) used here provides more accurate figures for RTI, and our ratio estimates are based on more recent TBI studies. Furthermore, the higher prevalence of mild TBI in our estimate probably explains some of these disparities.

In calculating the incidence figures herein, we relied on RTI data from the IHME since reliable, population-based incidence figures for TBI in the majority of LMICs were unavailable—both in the literature and via national registries. Relative ratios of TBI occurrence, as well as the contribution of RTI to overall TBI, obtained via systematic review and meta-analysis are subject to multiple sources of bias. Any small difference or inaccuracy in the TBI/RTI

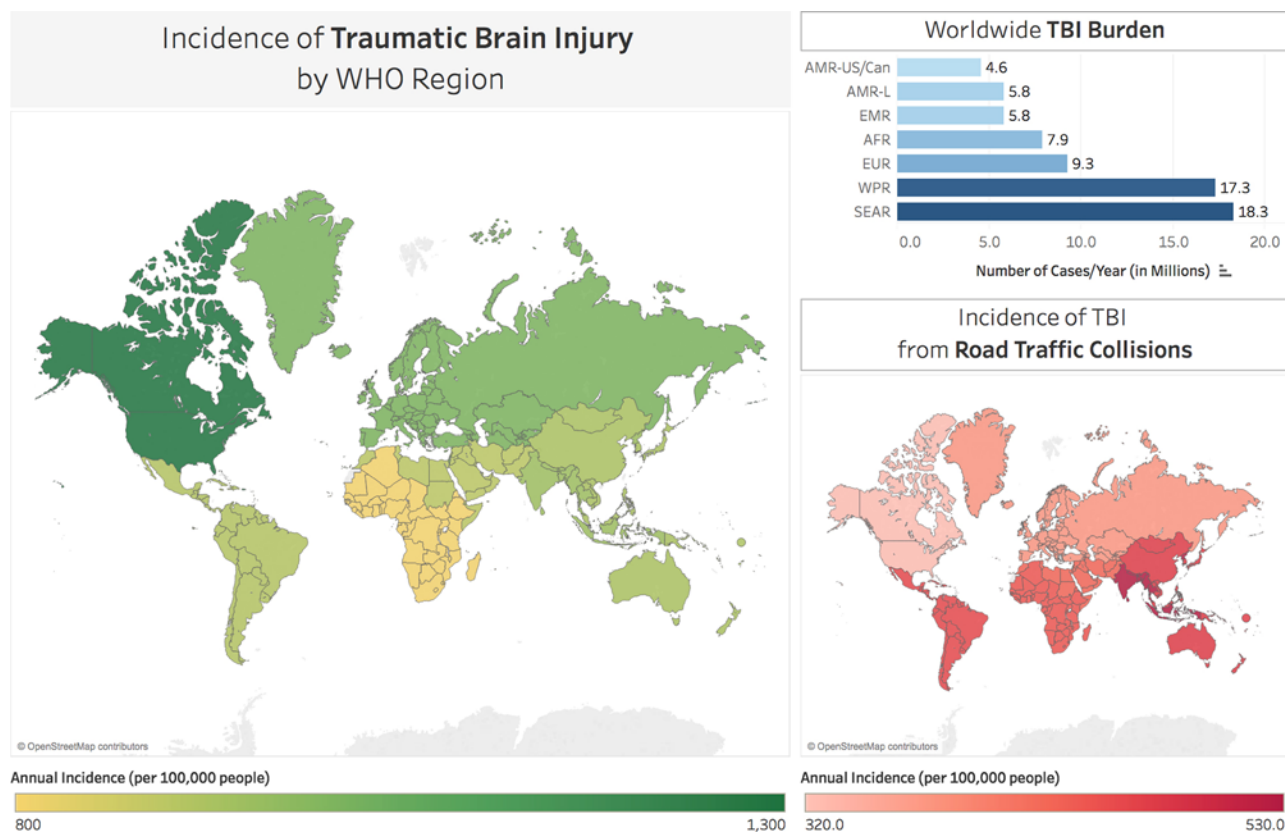


FIG. 4. Map showing incidence of TBI (cases per 100,000 people) by WHO region (*left*). Bar graph (*upper right*) indicating the estimated volume of TBI annually across WHO regions. Map (*lower right*) showing incidence of TBI (cases per 100,000 people) secondary to traffic collisions by WHO region. Regarding maps, reproduced with permission from OpenStreetMap Contributors, CC BY-SA 2.0 (<http://www.openstreetmap.org/copyright>). Figure is available in color online only.

ratio is compounded when applied to P(RTI) and regional populations. For example, in this model, a low P(RTI|TBI) will boost regional TBI incidence because incidence is calculated from the product of P(RTI) and the inverse of P(RTI|TBI). The incidence of TBI in the AMR-US/Can probably stands as an outlier in part for this very reason. While also relatively high, the EUR incidence (1012 cases per 100,000 people) is somewhat diluted by MICs, in which less robust, hospital-derived data tend to produce lower overall TBI incidence rates because some cases of mild TBI are never reported. The lower TBI incidence in the AFR is probably explained in part by lower-quality road traffic data from member countries, as well as by the overwhelming contribution of RTIs to TBI. In this model, the contribution of all other MOIs (recreation, falls, assault, and so forth) is incorporated indirectly by the inverse proportion of TBIs from RTIs (Fig. 1).

Nevertheless, several observations lending credence to our estimates warrant elaboration. First, our meta-regression suggests that P(TBI|RTI) is highest in the AFR (34%) and SEAR (34%) and lowest in the AMR-US/Can (29%). This is an intuitive finding given the abundance of traffic regulations and safety laws in places like the United States relative to many LICs.^{52,203} Additionally, RTI refers to injuries sustained not only by motorists, but also by pedestrians and cyclists. A dearth of sidewalks and traffic lights and poor helmet compliance among cyclists and motor-

cyclists in LMICs probably translate to a higher rate of HI following RTI.^{66,100,220} Moreover, inadequate on-board safety technology or overcapacity vehicles can compound an otherwise trivial collision. The single collision of a cargo truck full of unrestrained occupants in LMICs can result in dozens of cases of TBI—a scenario not frequently observed in most HICs.

Second, we found that P(RTI|TBI) was lowest in the AMR-US/Can (25%) and highest in the SEAR (56%) and AFR (56%). A larger proportion of studies from the SEAR and AFR represented hospital-based analyses relative to studies from regions with a predominance of HICs (Supplemental Table S2). As a result, TBI presenting to hospitals in LMICs likely overrepresented high-severity injuries, which are known to be associated with road traffic collisions more than other MOIs.^{5,185,187,252} Furthermore, in many HICs, in which life expectancy exceeds that in LMICs, injury secondary to falls, especially in the elderly, tends to dilute the overall mechanistic proportion of TBI; our results suggest that this phenomenon may exist.^{18,112}

Mild TBI occurs with far greater frequency than moderate or severe TBI—nearly 10-fold the burden of both moderate and severe injury. When establishing health care priorities in the setting of limited resources, some may dismiss this mild TBI burden as being of nominal consequence. However, the disabling effects of even mild TBI probably translate into economic, societal, and qual-

ity of life detriments. Nearly a quarter of patients describe disabling symptoms several months after injury.^{195,268} And despite the normalization of neuropsychological and functional scales by 1 year, half of TBI victims report 3 or more persistent posttraumatic symptoms.⁶⁸

The volume and extent of our literature review attempts not only to address our stated hypotheses, but also to aid researchers interested in exploring these hypotheses further. The tremendous amount of data found within these studies cannot possibly be summarized in a single paper; instead, highlights and major patterns are described in the text and tables. Readers are encouraged to consult the Supplemental Tables to gain a more granular understanding of the nature of TBI in regions around the world. Supplemental Table S2 is organized by WHO region and country to serve as a quick reference for the interested reader and those seeking an understanding of the data available in—and absent from—the literature.

Limitations and Future Directions

The conclusions of this report must be examined in the context of our study design. First, all TBI estimates were modeled after the GBD estimates for RTI. Therefore, assumptions or errors made in the GBD methodology would be carried over into these estimates. Second, by nature of the data available from the literature, we assumed uniform disease susceptibility across age groups and sexes. We also assumed that member countries of a particular WHO region or WB income group share the same injury incidence and proportion. The gold-standard alternative to this limitation is a series of large, population-based sampling studies conducted in every representative population worldwide; the feasibility and cost of such an effort is problematic, though no less important.

Next, the literature reviews and meta-analyses conducted to obtain RTI and TBI relative ratios rely on heterogeneous and often biased study designs. Naturally, a topic as broad as TBI yields results from non-uniform populations, thereby making aggregations and direct comparisons challenging. For example, in the latter systematic review, some studies only examined severe TBI^{84,243,257} and some only reported on TBI in young^{188,194,197,241,243,245,254,258,265} or elderly^{48,49,134,225} cohorts. Combining epidemiological data across disparate cohorts risks misrepresentation of the disease burden and volume. Moreover, the methodological quality from LMICs was, on average, lower than that from HICs; the TBI estimates from HICs may be more reliable than those from LMICs. This limitation is inherent to most global epidemiological surveys, wherein data derive from sources of disparate quality. Lastly, even basic discrepancies, such as differing definitions of TBI or conflicting injury severity scores, encountered across studies may have influenced our results.

Despite the limitations of this model and its underlying methodology, justification for its use resides in the scientific estimation of TBI burden in countries and regions in which data are otherwise entirely unavailable. Our aim of estimating the volume of TBI on a global scale in a transparent and quantitative fashion has been realized, albeit with the aforementioned considerations. Concrete estimates of TBI with region and income-level specificity are provided.

A tremendous burden—approximately 69 million cases—of TBI can be expected each year. The vast majority of this burden affects populations in LMICs, in which adequate health care resources are often either inaccessible or nonexistent. Examining the disease burden between regions and comparing against available resources allow identification of such deficits in existing health care coverage. More robust research, especially in LMICs where high-quality data are deficient, is essential for a targeted campaign. A logical first step in this effort is the establishment of an international TBI registry to improve our understanding of the nature and scope of TBI worldwide. Such a registry should be intuitive, secure, electronic, transferable across heterogeneous institutional informational technologies, and free. While there are multiple such platforms available, we have extensive experience with REDCap¹⁰⁵ (Research Electronic Data Capture, Vanderbilt University) and its successful application in international data collection for clinical neurosurgery in LMICs. Secondly—and concurrently—a series of targeted, community-based epidemiological surveys of representative populations would allow for the generation of more reliable incidence and mortality figures for TBI in low-resource settings. Ultimately, curbing the silent epidemic of TBI will require a multipronged effort toward public awareness, safety legislation and enforcement, injury prevention campaigns, health care capacity strengthening, and community-based efforts to promote recovery and rehabilitation.

Conclusions

Each year an estimated 69 million individuals will suffer a TBI, the vast majority of which will be mild (81%) and moderate (11%) in severity. Per capita, the highest annual incidence of all-cause TBI is observed in the AMR-US/Can and EUR (1299 and 1012 cases per 100,000 people, respectively). Taking into account regional populations, however, the greatest burden of HIs is in the SEAR (18.3 million) and WPR (17.3 million). The health care systems in LMICs encounter nearly 3 times as many total TBIs than those in HICs. These estimates are limited by relatively low-quality data from LMICs and suggest the need for more robust and accurate injury reporting. The global disparity in health care between regions with fewer resources and a high disease burden and those with greater assets and a lower burden deserves attention and action.

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Appendix

Search Terms for Incidence of TBI From RTI

A series of 4 search parameters were used in PubMed (1, 2, 4) and PubMed Central (3):

- 1) “vehicular accident”[ti] OR “traffic accident”[ti]
Titles: 631; Abstracts reviewed: 50; Full texts reviewed: 8
- 2) (“vehicular accidents” AND “traumatic brain injury”) OR

("traffic accident" AND "traumatic brain injury") OR ("road accident" AND "traumatic brain injury") OR ("vehicular crash" AND "traumatic brain injury")

Titles: 88; Abstracts reviewed: 10; Full texts reviewed: 5

3) (vehicular accidents AND "traumatic brain injury") OR (traffic accident AND "traumatic brain injury") OR (road accident AND "traumatic brain injury") OR (vehicular crash AND "traumatic brain injury")

Titles: 565; Abstracts reviewed: 50; Full texts reviewed: 7

4) road traffic accidents[tiab] AND (injury[tiab] OR injuries[tiab] OR trauma[tiab] OR traumas[tiab] OR traumatic[tiab]) AND (brain[tiab] OR head[tiab])

Titles: 345; Abstracts reviewed: 83; Full texts reviewed: 36

Abstracts were selected if content was suggestive of an epidemiological study that categorized types of injuries sustained from RTIs. Full texts were selected if the abstract stated or suggested that the study contained the proportion of RTIs leading to HIs or TBIs. Final articles were included if the study provided sufficient information to calculate a proportion of TBI or HI.

Articles were excluded for the following reasons:

- 1) Included causes of HI other than RTIs
- 2) Entire study population had HI or TBI
- 3) Sample size under 100
- 4) Studies conducted before 2000
- 5) Head injury cases unclear to decipher
- 6) Strict conditions of HI cases examined (for example, severe or mild cases only)

Search Terms for TBI Mechanism of Injury and Severity Distribution

((("epidemiology" [Subheading] OR "Epidemiology"[MeSH] OR epidemiology[tiab] OR epidemiological[tiab] OR population[tiab] OR population-based[tiab] OR incident*[tiab] OR prevalent*[tiab] OR burden OR ratio[tiab] OR DALY[tiab] OR "disability adjusted life year*[tiab] OR YLL[tiab] OR "years of life lost"[tiab] OR YLD[tiab] OR "years lost to disability"[tiab] OR "years lost due to disability"[tiab] OR ratio[tiab] OR QALY[tiab] OR "quality adjusted life year*[tiab]))

AND

("Head Injuries, Penetrating"[MeSH] OR "Head Injuries, Closed"[MeSH] OR "Brain Injuries"[MeSH] OR "Intracranial Hemorrhage, Traumatic"[MeSH] OR brain injur*[tiab] OR head injur*[tiab]))

AND

("Africa"[MeSH] OR "Asia"[MeSH] OR "Central America"[MeSH] OR "Developing Countries"[MeSH] OR "Geographical Locations Category"[MeSH] OR "Internationality"[MeSH] OR "Latin America"[MeSH] OR "South America"[MeSH] OR "Dominican Republic"[tiab] OR "Principe"[tiab] OR "Puerto Rico"[tiab] OR "Sao Tome"[tiab] OR "Saudi Arabia"[tiab] OR "Sierra Leone"[tiab] OR "Virgin Islands"[tiab] OR Afghanistan*[tiab] OR Africa*[tiab] OR Albania*[tiab] OR Algeria*[tiab] OR America*[tiab] OR Andorra*[tiab] OR Angola*[tiab] OR Antarct*[tiab] OR Antigua*[tiab] OR Arab Emirate*[tiab] OR Argentina*[tiab] OR Armenia*[tiab] OR Aruba*[tiab] OR Asia*[tiab] OR Atlantic[tiab] OR Australia*[tiab] OR Austria*[tiab] OR Azerbaijan*[tiab] OR Azores Islands[tiab] OR Baham*[tiab] OR Bahra*[tiab] OR Bangladesh*[tiab] OR Barbad*[tiab] OR Barbuda*[tiab] OR Barthelmy[tiab] OR Barthélemy[tiab] OR Belarus*[tiab] OR Belg*[tiab] OR Belize[tiab] OR Bengali[tiab] OR Benin*[tiab] OR Bermuda*[tiab] OR Bhutan*[tiab] OR Bissau[tiab] OR Bolivia*[tiab] OR Bosnia*[tiab] OR Botswana*[tiab] OR Brazil*[tiab] OR Brunei[tiab] OR Bulgaria*[tiab] OR Burkina Faso[tiab] OR Burma[tiab] OR Burmese*[tiab] OR Burundi*[tiab] OR Cabo Verd*[tiab] OR Caicos[tiab] OR Cambodia*[tiab] OR Cameroon*[tiab] OR Canad*[tiab] OR Cape Verd*[tiab] OR Cayman[tiab] OR Central[tiab] OR Chad*[tiab] OR Chile[tiab] OR China[tiab] OR Chinese[tiab] OR Colombia*[tiab] OR

Comoros[tiab] OR Congo*[tiab] OR Costa Rica*[tiab] OR Cote[tiab] OR Cote d'Ivoire[tiab] OR Croatia*[tiab] OR Cuba[tiab] OR Cuban[tiab] OR Cyprus[tiab] OR Czech Republic[tiab] OR Denmark[tiab] OR developing countr*[tiab] OR developing nation*[tiab] OR Djibouti[tiab] OR Dominica*[tiab] OR East[tiab] OR East Timor[tiab] OR Ecuador*[tiab] OR Egypt*[tiab] OR El Salvador*[tiab] OR Eritrea*[tiab] OR Estonia*[tiab] OR Ethiopia*[tiab] OR Europ*[tiab] OR Fiji*[tiab] OR Finland[tiab] OR France[tiab] OR French Guiana[tiab] OR Gabon*[tiab] OR Gambia*[tiab] OR Gaza*[tiab] OR Georgia*[tiab] OR German*[tiab] OR Ghana*[tiab] OR Greece[tiab] OR Grenada*[tiab] OR Grenadines[tiab] OR Guadeloupe[tiab] OR Guatemala*[tiab] OR Guinea*[tiab] OR Guyan*[tiab] OR Haiti*[tiab] OR Herzegovina*[tiab] OR Hondura*[tiab] OR Hungary[tiab] OR Iceland*[tiab] OR income[tiab] OR India[tiab] OR Indian*[tiab] OR Indonesia*[tiab] OR Iran*[tiab] OR Iraq*[tiab] OR Ireland[tiab] OR Israel*[tiab] OR Italian[tiab] OR Italy[tiab] OR Ivory Coast[tiab] OR Jamaica*[tiab] OR Japan*[tiab] OR Jordan*[tiab] OR Kazakh*[tiab] OR Kenya*[tiab] OR Kiribati[tiab] OR Kitts[tiab] OR Korea*[tiab] OR Kosovar*[tiab] OR Kosovo[tiab] OR Kuwait*[tiab] OR Kyrgyz*[tiab] OR Lao[tiab] OR Laos*[tiab] OR Laotian*[tiab] OR latin america[tiab] OR Latvia[tiab] OR Lebanes*[tiab] OR Lebanon[tiab] OR Lebanese[tiab] OR Lesotho[tiab] OR less developed countr*[tiab] OR less developed nation*[tiab] OR Liberia*[tiab] OR Libya*[tiab] OR Liechtenstein[tiab] OR Lithuania[tiab] OR Imic[tiab] OR Imics[tiab] OR low income countr*[tiab] OR low income nation*[tiab] OR Lucia[tiab] OR Luxembourg[tiab] OR Macedonia*[tiab] OR Madagascar*[tiab] OR Madeira Island[tiab] OR Malawi*[tiab] OR Malaysia*[tiab] OR Maldives[tiab] OR Mali[tiab] OR Malta[tiab] OR Marshall Island*[tiab] OR Martinique[tiab] OR Mauritania*[tiab] OR Mauriti*[tiab] OR Mexican*[tiab] OR Mexico[tiab] OR Micronesia*[tiab] OR middle income countr*[tiab] OR middle income nation*[tiab] OR Moldova[tiab] OR Moldova*[tiab] OR Monaco[tiab] OR Mongolia*[tiab] OR Monteneg*[tiab] OR Montserrat[tiab] OR Morocc*[tiab] OR Mozambique[tiab] OR Myanmar[tiab] OR Namibia*[tiab] OR Nauru[tiab] OR Nepal*[tiab] OR Nevis[tiab] OR New Zealand[tiab] OR Nicaragua*[tiab] OR Niger*[tiab] OR Nigeria*[tiab] OR North[tiab] OR Norway[tiab] OR Oman*[tiab] OR Pacific[tiab] OR Pakistan*[tiab] OR Palau[tiab] OR Palestin*[tiab] OR Panama*[tiab] OR Papua[tiab] OR Paraguay*[tiab] OR Peru*[tiab] OR Philippin*[tiab] OR Poland[tiab] OR poor countr*[tiab] OR poor nation*[tiab] OR Portug*[tiab] OR Principe[tiab] OR Qatar*[tiab] OR Romania*[tiab] OR Russia*[tiab] OR Rwanda*[tiab] OR Saint Lucia[tiab] OR Saint Vincent[tiab] OR Samoa*[tiab] OR San Marino[tiab] OR Sao Tome[tiab] OR Senegal*[tiab] OR Serbia*[tiab] OR Seychelles[tiab] OR Sierra Leone*[tiab] OR Singapore[tiab] OR Slovakia*[tiab] OR Slovenia*[tiab] OR Solomon[tiab] OR Solomon Island*[tiab] OR Somalia*[tiab] OR South [tiab] OR Spain[tiab] OR Sri Lanka[tiab] OR Sudan*[tiab] OR Suriname*[tiab] OR Swaziland*[tiab] OR Swed*[tiab] OR Switzerland[tiab] OR Syria*[tiab] OR Taiwan[tiab] OR Tajik*[tiab] OR Tanzania*[tiab] OR Thai*[tiab] OR third world countr*[tiab] OR third world nation*[tiab] OR Timor Leste[tiab] OR Timor*[tiab] OR Tobago[tiab] OR Togo*[tiab] OR Tonga*[tiab] OR Trinidad*[tiab] OR Tunisia*[tiab] OR Turkey[tiab] OR Turkish[tiab] OR Turkmen*[tiab] OR Turks[tiab] OR Tuvalu*[tiab] OR Uganda*[tiab] OR Ukrain*[tiab] OR under developed countr*[tiab] OR under developed nation*[tiab] OR underdeveloped nation*[tiab] OR underdeveloped nation*[tiab] OR United Kingdom[tiab] OR United States[tiab] OR Uruguay[tiab] OR Uzbeki*[tiab] OR Vanuatu*[tiab] OR OR Vatican[tiab] OR Venezuela*[tiab] OR Viet nam*[tiab] OR Vietnam*[tiab] OR Vincent[tiab] OR West[tiab] OR West Bank[tiab] OR Yemen*[tiab] OR Zambia*[tiab] OR Zimbabw*[tiab])

NOT

("Animals"[MeSH] NOT "Humans"[MeSH])

References

- Adekoya N, Majumder R: Fatal traumatic brain injury, West Virginia, 1989–1998. **Public Health Rep** **119**:486–492, 2004
- Adeleye AO, Olowookere KG, Olayemi OO: Clinicoepidemiological profiles and outcomes during first hospital admission of head injury patients in Ikeja, Nigeria. A prospective cohort study. **Neuroepidemiology** **32**:136–141, 2009
- Aenderl I, Gashaw T, Siebeck M, Mutschler W: Head injury—a neglected public health problem: a four-month prospective study at Jimma University Specialized Hospital, Ethiopia. **Ethiop J Health Sci** **24**:27–34, 2014
- Agarwal-Harding KJ, Meara JG, Greenberg SLM, Hagander LE, Zurakowski D, Dyer GSM: Estimating the global incidence of femoral fracture from road traffic collisions: a literature review. **J Bone Joint Surg Am** **97**:e31, 2015
- Agius S, Ansari S, Zrinzo A: Pattern of head injuries in Malta (EU): a small Mediterranean island. **Br J Neurosurg** **26**:212–215, 2012
- Agrawal A, Agrawal CS, Kumar A, Lewis O, Malla G, Khatiwada R, et al: Epidemiology and management of paediatric head injury in eastern Nepal. **Afr J Paediatr Surg** **5**:15–18, 2008
- Agrawal A, Galwankar S, Kapil V, Coronado V, Basavaraju SV, McGuire LC, et al: Epidemiology and clinical characteristics of traumatic brain injuries in a rural setting in Maharashtra, India. 2007–2009. **Int J Crit Illn Inj Sci** **2**:167–171, 2012
- Agrawal D, Ahmed S, Khan S, Gupta D, Sinha S, Satyarthee GD: Outcome in 2068 patients of head injury: experience at a level 1 trauma centre in India. **Asian J Neurosurg** **11**:143–145, 2016
- Akama MK, Chindia ML, Macigo FG, Guthua SW: Pattern of maxillofacial and associated injuries in road traffic accidents. **East Afr Med J** **84**:287–295, 2007
- Al-Habib A, A-Shail A, Alaqeel A, Zamakhshary M, Al-Bedah K, Alqunai M, et al: Causes and patterns of adult traumatic head injuries in Saudi Arabia: implications for injury prevention. **Ann Saudi Med** **33**:351–355, 2013 (**Ann Saudi Med** **34**:91, 2014)
- Ala-Seppälä H, Heino I, Frantzén J, Takala RSK, Katila AJ, Kyllönen A, et al: Injury profiles, demography and representativeness of patients with TBI attending a regional emergency department. **Brain Inj** **30**:1062–1067, 2016
- Albrecht JS, Hirshon JM, McCunn M, Bechtold KT, Rao V, Simoni-Wastila L, et al: Increased rates of mild traumatic brain injury among older adults in US emergency departments, 2009–2010. **J Head Trauma Rehabil** **31**:E1–E7, 2016
- Aldawood AS, Alsultan M, Haddad S, Alqahtani SM, Tamim H, Arabi YM: Trauma profile at a tertiary intensive care unit in Saudi Arabia. **Ann Saudi Med** **32**:498–501, 2012
- Alhabdan S, Zamakhshary M, AlNaimi M, Mandora H, Alhamdan M, Al-Bedah K, et al: Epidemiology of traumatic head injury in children and adolescents in a major trauma center in Saudi Arabia: implications for injury prevention. **Ann Saudi Med** **33**:52–56, 2013
- Amaranath JE, Ramanan M, Reagh J, Saekang E, Prasad N, Chaseling R, et al: Epidemiology of traumatic head injury from a major paediatric trauma centre in New South Wales, Australia. **ANZ J Surg** **84**:424–428, 2014
- Andelic N, Anke A, Skandsen T, Sigurdardottir S, Sandhaug M, Ader T, et al: Incidence of hospital-admitted severe traumatic brain injury and in-hospital fatality in Norway: a national cohort study. **Neuroepidemiology** **38**:259–267, 2012
- Andelic N, Sigurdardottir S, Brunborg C, Roe C: Incidence of hospital-treated traumatic brain injury in the Oslo population. **Neuroepidemiology** **30**:120–128, 2008
- Andersson EH, Björklund R, Emanuelson I, Ståhlhammar D: Epidemiology of traumatic brain injury: a population based study in western Sweden. **Acta Neurol Scand** **107**:256–259, 2003
- Andriessen TMJC, Horn J, Franschman G, van der Naalt J, Haitsma I, Jacobs B, et al: Epidemiology, severity classification, and outcome of moderate and severe traumatic brain injury: a prospective multicenter study. **J Neurotrauma** **28**:2019–2031, 2011
- Arnarson EO, Halldórsson JG: Head trauma among children in Reykjavík. **Acta Paediatr** **84**:96–99, 1995
- Asemota AO, George BP, Bowman SM, Haider AH, Schneider EB: Causes and trends in traumatic brain injury for United States adolescents. **J Neurotrauma** **30**:67–75, 2013
- Atzema C, Mower WR, Hoffman JR, Holmes JF, Killian AJ, Wolfson AB, et al: Prevalence and prognosis of traumatic intraventricular hemorrhage in patients with blunt head trauma. **J Trauma** **60**:1010–1017, 2006
- Avesani R, Roncari L, Khansefid M, Formisano R, Boldrini P, Zampolini M, et al: The Italian National Registry of severe acquired brain injury: epidemiological, clinical and functional data of 1469 patients. **Eur J Phys Rehabil Med** **49**:611–618, 2013
- Bachani AM, Koradia P, Herbert HK, Mogere S, Akungah D, Nyamari J, et al: Road traffic injuries in Kenya: the health burden and risk factors in two districts. **Traffic Inj Prev** **13** (Suppl 1):24–30, 2012
- Bahloul M, Chelly H, Ben Hmida M, Ben Hamida C, Ksibi H, Kallel H, et al: Prognosis of traumatic head injury in South Tunisia: a multivariate analysis of 437 cases. **J Trauma** **57**:255–261, 2004
- Bahloul M, Chelly H, Gargouri R, Dammak H, Kallel H, Ben Hamida C, et al: [Traumatic head injury in children in south Tunisia epidemiology, clinical manifestations and evolution. 454 cases.] **Tunis Med** **87**:28–37, 2009 (Fr)
- Bajracharya A, Agrawal A, Yam B, Agrawal C, Lewis O: Spectrum of surgical trauma and associated head injuries at a university hospital in eastern Nepal. **J Neurosci Rural Pract** **1**:2–8, 2010
- Baldo V, Marcolongo A, Floreani A, Majori S, Cristoforetti M, Dal Zotto A, et al: Epidemiological aspect of traumatic brain injury in Northeast Italy. **Eur J Epidemiol** **18**:1059–1063, 2003
- Banthia P, Koirala B, Rauniyar A, Chaudhary D, Kharel T, Khadka SB: An epidemiological study of road traffic accident cases attending emergency department of teaching hospital. **JNMA J Nepal Med Assoc** **45**:238–243, 2006
- Barker-Collo SL, Wilde NJ, Feigin VL: Trends in head injury incidence in New Zealand: a hospital-based study from 1997/1998 to 2003/2004. **Neuroepidemiology** **32**:32–39, 2009
- Bayreuther J, Wagener S, Woodford M, Edwards A, Lecky F, Bouamra O, et al: Paediatric trauma: injury pattern and mortality in the UK. **Arch Dis Child Educ Pract Ed** **94**:37–41, 2009
- Bener A, Abdul Rahman YS, Abdel Aleem EY, Khalid MK: Trends and characteristics of head and neck injury from falls: a hospital based study, Qatar. **Sultan Qaboos Univ Med J** **11**:244–251, 2011
- Bener A, Omar AOK, Ahmad AE, Al-Mulla FH, Abdul Rahman YS: The pattern of traumatic brain injuries: a country undergoing rapid development. **Brain Inj** **24**:74–80, 2010
- Berry JG, Jamieson LM, Harrison JE: Head and traumatic brain injuries among Australian children, July 2000–June 2006. **Inj Prev** **16**:198–202, 2010

35. Bhatti J, Stevens K, Mir M, Hyder AA, Razzak J: Emergency care of traumatic brain injuries in Pakistan: a multicenter study. *BMC Emerg Med* **15** (Suppl 2):S12, 2015
36. Boniface R, Museru L, Kiloloma O, Munthali V: Factors associated with road traffic injuries in Tanzania. *Pan Afr Med J* **23**:46, 2016
37. Bowman SM, Bird TM, Aitken ME, Tilford JM: Trends in hospitalizations associated with pediatric traumatic brain injuries. *Pediatrics* **122**:988–993, 2008
38. Brazinova A, Mauritz W, Majdan M, Rehorcikova V, Leitgeb J: Fatal traumatic brain injury in older adults in Austria 1980–2012: an analysis of 33 years. *Age Ageing* **44**:502–506, 2015
39. Bryan-Hancock C, Harrison J: The global burden of traumatic brain injury: preliminary results from the Global Burden of Disease Project. *Inj Prev* **16**:A17, 2011
40. Burrows P, Trefan L, Houston R, Hughes J, Pearson G, Edwards RJ, et al: Head injury from falls in children younger than 6 years of age. *Arch Dis Child* **100**:1032–1037, 2015
41. Cadotte DW, Vachhrajani S, Pirouzmand F: The epidemiological trends of head injury in the largest Canadian adult trauma center from 1986 to 2007. *J Neurosurg* **114**:1502–1509, 2011
42. Centers for Disease Control and Prevention: Incidence rates of hospitalization related to traumatic brain injury—12 states, 2002. *MMWR Morb Mortal Wkly Rep* **55**:201–204, 2006
43. Centers for Disease Control and Prevention: Rates of hospitalization related to traumatic brain injury—nine states, 2003. *MMWR Morb Mortal Wkly Rep* **56**:167–170, 2007
44. Centers for Disease Control and Prevention: Traumatic brain injury—Colorado, Missouri, Oklahoma, and Utah, 1990–1993. *MMWR Morb Mortal Wkly Rep* **46**:8–11, 1997
45. Centers for Disease Control and Prevention: **Traumatic Brain Injury in the United States: Emergency Department Visits, Hospitalizations and Deaths 2002–2006**. Atlanta: Centers for Disease Control and Prevention, 2010
46. Chalya PL, Mabula JB, Dass RM, Mbelenge N, Ngayomela IH, Chandika AB, et al: Injury characteristics and outcome of road traffic crash victims at Bugando Medical Centre in Northwestern Tanzania. *J Trauma Manag Outcomes* **6**:1, 2012
47. Chan HC, Aasim WAW, Abdullah NM, Naing NN, Abdullah JM, Saffari MHM, et al: Characteristics and clinical predictors of minor head injury in children presenting to two Malaysian accident and emergency departments. *Singapore Med J* **46**:219–223, 2005
48. Chan V, Zagorski B, Parsons D, Colantonio A: Older adults with acquired brain injury: a population based study. *BMC Geriatr* **13**:97, 2013
49. Cheng PL, Lin HY, Lee YK, Hsu CY, Lee CC, Su YC: Higher mortality rates among the elderly with mild traumatic brain injury: a nationwide cohort study. *Scand J Trauma Resusc Emerg Med* **22**:7, 2014
50. Chiavaroli F, Derraik JGB, Zani G, Lavezzi S, Chiavaroli V, Sherwin E, et al: Epidemiology and clinical outcomes in a multicentre regional cohort of patients with severe acquired brain injury. *Disabil Rehabil* **38**:2038–2046, 2016
51. Chinda JY, Abubakar AM, Umaru H, Tahir C, Adamu S, Wabada S: Epidemiology and management of head injury in paediatric age group in North-Eastern Nigeria. *Afr J Paediatr Surg* **10**:358–361, 2013
52. Chiu WT, Huang SJ, Tsai SH, Lin JW, Tsai MD, Lin TJ, et al: The impact of time, legislation, and geography on the epidemiology of traumatic brain injury. *J Clin Neurosci* **14**:930–935, 2007
53. Chong SL, Chew SY, Feng JXY, Teo PYL, Chin ST, Liu N, et al: A prospective surveillance of paediatric head injuries in Singapore: a dual-centre study. *BMJ Open* **6**:e010618, 2016
54. Colantonio A, Croxford R, Farooq S, Laporte A, Coyte PC: Trends in hospitalization associated with traumatic brain injury in a publicly insured population, 1992–2002. *J Trauma* **66**:179–183, 2009
55. Colantonio A, Saverino C, Zagorski B, Swaine B, Lewko J, Jaglal S, et al: Hospitalizations and emergency department visits for TBI in Ontario. *Can J Neurol Sci* **37**:783–790, 2010
56. Compagnone C, d'Avella D, Servadei F, Angileri FF, Brambilla G, Conti C, et al: Patients with moderate head injury: a prospective multicenter study of 315 patients. *Neurosurgery* **64**:690–697, 2009
57. Coronado VG, McGuire LC, Sarmiento K, Bell J, Lionbarger MR, Jones CD, et al: Trends in traumatic brain injury in the U.S. and the public health response: 1995–2009. *J Safety Res* **43**:299–307, 2012
58. Crowe L, Babl F, Anderson V, Catroppa C: The epidemiology of paediatric head injuries: data from a referral centre in Victoria, Australia. *J Paediatr Child Health* **45**:346–350, 2009
59. Crowe LM, Catroppa C, Anderson V, Babl FE: Head injuries in children under 3 years. *Injury* **43**:2141–2145, 2012
60. Cuthbert JP, Harrison-Felix C, Corrigan JD, Kreider S, Bell JM, Coronado VG, et al: Epidemiology of adults receiving acute inpatient rehabilitation for a primary diagnosis of traumatic brain injury in the United States. *J Head Trauma Rehabil* **30**:122–135, 2015
61. Dahl E, von Wendt L, Emanuelson I: A prospective, population-based, follow-up study of mild traumatic brain injury in children. *Injury* **37**:402–409, 2006
62. Daniëlle van Pelt E, de Kloet A, Hilberink SR, Lambregts SAM, Peeters E, Roebroek ME, et al: The incidence of traumatic brain injury in young people in the catchment area of the University Hospital Rotterdam, The Netherlands. *Eur J Paediatr Neurol* **15**:519–526, 2011
63. de Almeida CER, de Sousa Filho JL, Dourado JC, Gontijo PAM, Dellaretti MA, Costa BS: Traumatic brain injury epidemiology in Brazil. *World Neurosurg* **87**:540–547, 2016
64. de Kloet AJ, Hilberink SR, Roebroek ME, Catsman-Berrevoets CE, Peeters E, Lambregts SAM, et al: Youth with acquired brain injury in The Netherlands: a multi-centre study. *Brain Inj* **27**:843–849, 2013
65. Department for Transport: Hospital admissions as a result of road accidents (RAS55). *GOV.UK*. (<https://www.gov.uk/government/statistical-data-sets/ras55-hospital-episode-statistics-hes>) [Accessed January 10, 2018]
66. Dewan MC, Mummareddy N, Wellons JC III, Bonfield CM: Epidemiology of global pediatric traumatic brain injury: qualitative review. *World Neurosurg* **91**:497–509, 509.e1, 2016
67. Dias C, Rocha J, Pereira E, Cerejo A: Traumatic brain injury in Portugal: trends in hospital admissions from 2000 to 2010. *Acta Med Port* **27**:349–356, 2014
68. Dikmen S, Machamer J, Temkin N: Mild traumatic brain injury: longitudinal study of cognition, functional status, and post-traumatic symptoms. *J Neurotrauma* **34**:1524–1530, 2017
69. du Toit-Prinsloo L, Saayman G: Fatal head injuries in children under the age of 5 years in Pretoria. *Am J Forensic Med Pathol* **35**:212–217, 2014
70. Durkin MS, Olsen S, Barlow B, Virella A, Connolly ES Jr: The epidemiology of urban pediatric neurological trauma: evaluation of, and implications for, injury prevention programs. *Neurosurgery* **42**:300–310, 1998
71. Eisele JA, Kegler SR, Trent RB, Coronado VG: Nonfatal

- traumatic brain injury-related hospitalization in very young children—15 states, 1999. **J Head Trauma Rehabil** **21**:537–543, 2006
72. El-Matbouly M, El-Menyar A, Al-Thani H, Tuma M, El-Hennawy H, AbdulRahman H, et al: Traumatic brain injury in Qatar: age matters—insights from a 4-year observational study. **Sci World J** **2013**:354920–354926, 2013
 73. Emanuelson I, v Wendt L: Epidemiology of traumatic brain injury in children and adolescents in south-western Sweden. **Acta Paediatr** **86**:730–735, 1997
 74. Emejulu JKC: Epidemiological patterns of head injury in a newly established neurosurgical service: one-year prospective study. **Afr J Med Med Sci** **37**:383–388, 2008
 75. Emejulu JKC, Shokunbi MT: Aetiological patterns and management outcome of paediatric head trauma: one-year prospective study. **Niger J Clin Pract** **13**:276–279, 2010
 76. Engberg AW, Teasdale TW: [Epidemiology and treatment of head injuries in Denmark 1994–2002, illustrated with hospital statistics.] **Ugeskr Laeger** **169**:199–203, 2007
 77. Engberg A, Teasdale TW: Traumatic brain injury in children in Denmark: a national 15-year study. **Eur J Epidemiol** **14**:165–173, 1998
 78. Engberg AW, Teasdale TW: Traumatic brain injury in Denmark 1979–1996. A national study of incidence and mortality. **Eur J Epidemiol** **17**:437–442, 2001
 79. Fabbri A, Servadei F, Marchesini G, Negro A, Vandelli A: The changing face of mild head injury: temporal trends and patterns in adolescents and adults from 1997 to 2008. **Injury** **41**:913–917, 2010
 80. Fakharian E, Mohammadzadeh M, Behdad S, Babamohammadi A, Mirzadeh AS, Mohammadzadeh J: A seven-year study on head injuries in infants, Iran—the changing pattern. **Chin J Traumatol** **17**:153–156, 2014
 81. Falk AC, Klang B, Paaavonen EJ, von Wendt L: Current incidence and management of children with traumatic head injuries: the Stockholm experience. **Dev Neurorehabil** **10**:49–55, 2007 (Erratum in **Dev Neurorehabil** **10**:267, 2007)
 82. Feigin VL, Forouzanfar MH, Krishnamurthi R, Mensah GA, Connor M, Bennett DA, et al: Global and regional burden of stroke during 1990–2010: findings from the Global Burden of Disease Study 2010. **Lancet** **383**:245–254, 2014
 83. Feigin VL, Theadom A, Barker-Collo S, Starkey NJ, McPherson K, Kahan M, et al: Incidence of traumatic brain injury in New Zealand: a population-based study. **Lancet Neurol** **12**:53–64, 2013
 84. Feinberg M, Mai J, Ecklund J: Neurosurgical management in traumatic brain injury. **Semin Neurol** **35**:050–056, 2015
 85. Feitas JPP, Ribeiro LA, Jorge MT: [Pediatric victims of traffic accidents admitted to a university hospital: epidemiological and clinical aspects]. **Cad Saude Publica** **23**:3055–3060, 2007 (Portuguese)
 86. Fekih Hassen A, Zayani MC, Friaa M, Trifa M, Ben Khalifa S: [Epidemiology of pediatric traumatic brain injury at the Children's Hospital of Tunisia, 2007.] **Tunis Med** **90**:25–30, 2012 (Fr)
 87. Fernández ML, Mejías L, Ortiz N, García-Fragoso L: Minor head injury in children younger than two years of age: description, prevalence and management in the emergency room of the pediatric university hospital. **Bol Asoc Med P R** **102**:26–28, 2010
 88. Ferreros I, Peiro S, Chirivella-Garrido J, Duque P, Gagliardo P, Perez-Vicente R, et al: [Incidence of hospitalization for traumatic brain injury in children and adolescents (Valencia Community, Spain, 2002–2009).] **Rev Neurol** **54**:719–728, 2012 (Span)
 89. Finnerty F, Glynn L, Dineen B, Colfer F, Macfarlane A: A postal survey of data in general practice on the prevalence of acquired brain injury (ABI) in patients aged 18–65 in one county in the west of Ireland. **BMC Fam Pract** **10**:36, 2009
 90. Firsching R, Woischneck D: Present status of neurosurgical trauma in Germany. **World J Surg** **25**:1221–1223, 2001
 91. Fletcher AE, Khalid S, Mallonee S: The epidemiology of severe traumatic brain injury among persons 65 years of age and older in Oklahoma, 1992–2003. **Brain Inj** **21**:691–699, 2007
 92. Frohlich S, Johnson P, Moriarty J: Prevalence, management and outcomes of traumatic brain injury patients admitted to an Irish intensive care unit. **Ir J Med Sci** **180**:423–427, 2011
 93. Fu TS, Jing R, Fu WW, Cusimano MD: Epidemiological trends of traumatic brain injury identified in the emergency department in a publicly-insured population, 2002–2010. **PLoS One** **11**:e0145469, 2016
 94. Fuller G, Bouamra O, Woodford M, Jenks T, Patel H, Coats TJ, et al: Temporal trends in head injury outcomes from 2003 to 2009 in England and Wales. **Br J Neurosurg** **25**:414–421, 2011
 95. Gabella B, Hoffman RE, Marine WW, Stallones L: Urban and rural traumatic brain injuries in Colorado. **Ann Epidemiol** **7**:207–212, 1997
 96. Gísladóttir EH, Karason S, Sigvaldason K, Ulfarsson E, Mogensen B: [Visits to an emergency department due to head injuries.] **Laeknabladid** **100**:331–335, 2014 (Icelandic)
 97. Gordon KE, Dooley JM, Wood EP: Descriptive epidemiology of concussion. **Pediatr Neurol** **34**:376–378, 2006
 98. Guerrero JL, Thurman DJ, Sniezek JE: Emergency department visits associated with traumatic brain injury: United States, 1995–1996. **Brain Inj** **14**:181–186, 2000
 99. Guillén-Pinto D, Zea-Vera A, Guillén-Mendoza D, Situ-Kcomt M, Reynoso-Osnayo C, Milla-Vera LM, et al: [Traumatic brain injury in children attending a national hospital in Lima, Peru 2004–2011.] **Rev Peru Med Exp Salud Publica** **30**:630–634, 2013 (Span)
 100. Gupta S, Iv V, Sam N, Vuthy D, Klaric K, Shrimel MG, et al: Impact of helmet use on severity of epidural hematomas in Cambodia. **World Neurosurg** **100**:267–270, 2017
 101. Halldorsson JG, Flekkoy KM, Arnkelsson GB, Tomasson K, Magnadottir HB, Arnarson EO: The scope of early traumatic brain injury as a long-term health concern in two nationwide samples: prevalence and prognostic factors. **Brain Inj** **26**:1–13, 2012
 102. Halldorsson JG, Flekkoy KM, Gudmundsson KR, Arnkelsson GB, Arnarson EO: Urban-rural differences in pediatric traumatic head injuries: a prospective nationwide study. **Neuropsychiatr Dis Treat** **3**:935–941, 2007
 103. Hamann C, Peek-Asa C, Rus D: Epidemiology of pedestrian-MVCs by road type in Cluj, Romania. **Inj Prev** **21**:84–90, 2015
 104. Hamilton M, Mrazik M, Johnson DW: Incidence of delayed intracranial hemorrhage in children after uncomplicated minor head injuries. **Pediatrics** **126**:e33–e39, 2010
 105. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG: Research electronic data capture (REDCap)—a metadata-driven methodology and workflow process for providing translational research informatics support. **J Biomed Inform** **42**:377–381, 2009
 106. Harrison JE, Berry JG, Jamieson LM: Head and traumatic brain injuries among Australian youth and young adults, July 2000–June 2006. **Brain Inj** **26**:996–1004, 2012
 107. Hartholt KA, Van Lieshout EMM, Polinder S, Panneman MJM, Van der Cammen TJM, Patka P: Rapid increase in hospitalizations resulting from fall-related traumatic head injury in older adults in The Netherlands 1986–2008. **J Neurotrauma** **28**:739–744, 2011
 108. Harvey LA, Close JCT: Traumatic brain injury in older adults: characteristics, causes and consequences. **Injury** **43**:1821–1826, 2012

109. Hawley C, Wilson J, Hickson C, Mills S, Ekeocha S, Sakr M: Epidemiology of paediatric minor head injury: comparison of injury characteristics with indices of multiple deprivation. **Injury** **44**:1855–1861, 2013
110. Hawley CA, Ward AB, Long J, Owen DW, Magnay AR: Prevalence of traumatic brain injury amongst children admitted to hospital in one health district: a population-based study. **Injury** **34**:256–260, 2003
111. Heim C, Bosisio F, Röth A, Bloch J, Borens O, Daniel RT, et al: Is trauma in Switzerland any different? Epidemiology and patterns of injury in major trauma—a 5-year review from a Swiss trauma centre. **Swiss Med Wkly** **144**:w13958, 2014
112. Heskestad B, Baardsen R, Helseth E, Romner B, Waterloo K, Ingebrigtsen T: Incidence of hospital referred head injuries in Norway: a population based survey from the Stavanger region. **Scand J Trauma Resusc Emerg Med** **17**:6, 2009
113. Hu J, Ugiliweneza B, Meyer K, Lad SP, Boakye M: Trend and geographic analysis for traumatic brain injury mortality and cost based on MarketScan database. **J Neurotrauma** **30**:1755–1761, 2013
114. Idowu OE, Akinbo O: Neurotrauma burden in a tropical urban conurbation level I trauma centre. **Injury** **45**:1717–1721, 2014
115. Ingebrigtsen T, Mortensen K, Romner B: The epidemiology of hospital-referred head injury in northern Norway. **Neuroepidemiology** **17**:139–146, 1998
116. Institute for Health Metrics and Evaluation: **Global Burden of Disease Study 2015: Incidence, Prevalence, and Years Lived with Disability 1990–2015**. Seattle: Institute for Health Metrics and Evaluation, 2016
117. Işık HS, Bostancı U, Yıldız O, Özdemir C, Gökyar A: [Retrospective analysis of 954 adult patients with head injury: an epidemiological study.] **Ulus Travma Acil Cerrahi Derg** **17**:46–50, 2011 (Turkish)
118. Işık HS, Gökyar A, Yıldız O, Bostancı U, Özdemir C: [Pediatric head injuries, retrospective analysis of 851 patients: an epidemiological study.] **Ulus Travma Acil Cerrahi Derg** **17**:166–172, 2011 (Turkish)
119. Jacobsson LJ, Westerberg M, Lexell J: Demographics, injury characteristics and outcome of traumatic brain injuries in northern Sweden. **Acta Neurol Scand** **116**:300–306, 2007
120. Jager TE, Weiss HB, Coben JH, Pepe PE: Traumatic brain injuries evaluated in U.S. emergency departments, 1992–1994. **Acad Emerg Med** **7**:134–140, 2000
121. Jagnoor J, Keay L, Ganguli A, Dandona R, Thakur JS, Boufous S, et al: Fall related injuries: a retrospective medical review study in North India. **Injury** **43**:1996–2000, 2012
122. Jaja BNR, Eghwrudjakpor PO: Effect of demographic and injury etiologic factors on intensive care unit mortality after severe head injury in a low middle income country. **Ann Afr Med** **13**:204–209, 2014
123. Jamieson LM, Roberts-Thomson KF: Hospitalized head injuries among older people in Australia, 1998/1999 to 2004/2005. **Inj Prev** **13**:243–247, 2007
124. Javouhey E, Guérin AC, Chiron M: Incidence and risk factors of severe traumatic brain injury resulting from road accidents: a population-based study. **Accid Anal Prev** **38**:225–233, 2006
125. Ji C, Duan L, Wang L, Wu C, Wang Y, Er Y, et al: [Study on head injuries through data from the National Injury Surveillance System of China, 2013.] **Zhonghua Liu Xing Bing Xue Za Zhi** **36**:360–363, 2015 (Chinese)
126. Jiang JY, Feng H, Fu Z, Guo-yi G, Wei-ping L, Wei-guo L, et al: Violent head trauma in China: report of 2254 cases. **Surg Neurol** **68** (Suppl 2):S2–S5, 2007
127. Kalanithi P, Schubert RD, Lad SP, Harris OA, Boakye M: Hospital costs, incidence, and in-hospital mortality rates of traumatic subdural hematoma in the United States. **J Neurosurg** **115**:1013–1018, 2011
128. Kamal VK, Agrawal D, Pandey RM: Epidemiology, clinical characteristics and outcomes of traumatic brain injury: evidences from integrated level I trauma center in India. **J Neurosci Rural Pract** **7**:515–525, 2016
129. Kaptigau WM, Ke L, Rosenfeld JV: Trends in traumatic brain injury outcomes in Port Moresby General Hospital from January 2003 to December 2004. **P N G Med J** **50**:50–57, 2007
130. Karibe H, Kameyama M, Kawase M, Hirano T, Kawaguchi T, Tominaga T: [Epidemiology of chronic subdural hematomas.] **No Shinkei Geka** **39**:1149–1153, 2011 (Jpn)
131. Katsaragakis S, Drimousis PG, Toutouzas K, Stefanatou M, Larentzakis A, Theodoraki ME, et al: Traumatic brain injury in Greece: report of a countrywide registry. **Brain Inj** **24**:871–876, 2010
132. Keenan HT, Runyan DK, Marshall SW, Nocera MA, Merten DF, Sinal SH: A population-based study of inflicted traumatic brain injury in young children. **JAMA** **290**:621–626, 2003
133. Kelly P, John S, Vincent AL, Reed P: Abusive head trauma and accidental head injury: a 20-year comparative study of referrals to a hospital child protection team. **Arch Dis Child** **100**:1123–1130, 2015
134. Khan A, Prince M, Brayne C, Prina AM: Lifetime prevalence and factors associated with head injury among older people in low and middle income countries: a 10/66 study. **PLoS One** **10**:e0132229, 2015
135. Kim HB, Kim DK, Kwak YH, Shin SD, Song KJ, Lee SC, et al: Epidemiology of traumatic head injury in Korean children. **J Korean Med Sci** **27**:437–442, 2012
136. King J, Haddock G: Neonatal head injuries revisited. **Scott Med J** **54**:34–36, 2009
137. Koepsell TD, Rivara FP, Vavilala MS, Wang J, Temkin N, Jaffe KM, et al: Incidence and descriptive epidemiologic features of traumatic brain injury in King County, Washington. **Pediatrics** **128**:946–954, 2011
138. Kool B, Chelimo C, Ameratunga S: Head injury incidence and mortality in New Zealand over 10 Years. **Neuroepidemiology** **41**:189–197, 2013
139. Kool B, Raj N, Wainiqolo I, Kafoa B, McCaig E, Ameratunga S: Hospitalised and fatal head injuries in Viti Levu, Fiji: findings from an island-wide trauma registry (TRIP 4). **Neuroepidemiology** **38**:179–185, 2012
140. Koskinen S, Alaranta H: Traumatic brain injury in Finland 1991–2005: a nationwide register study of hospitalized and fatal TBI. **Brain Inj** **22**:205–214, 2008
141. Kramer AH, Zygun DA, Doig CJ, Zuege DJ: Incidence of neurologic death among patients with brain injury: a cohort study in a Canadian health region. **CMAJ** **185**:E838–E845, 2013
142. Kraus JF, Fife D, Cox P, Ramstein K, Conroy C: Incidence, severity, and external causes of pediatric brain injury. **Am J Dis Child** **140**:687–693, 1986
143. Krause M, Richards S: Prevalence of traumatic brain injury and access to services in an undergraduate population: a pilot study. **Brain Inj** **28**:1301–1310, 2014
144. Lagbas C, Bazargan-Hejazi S, Shaheen M, Kermah D, Pan D: Traumatic brain injury related hospitalization and mortality in California. **BioMed Res Int** **2013**:143092–143099, 2013
145. Lagolago W, Theadom A, Fairbairn-Dunlop P, Ameratunga S, Dowell A, McPherson KM, et al: Traumatic brain injury within Pacific people of New Zealand. **N Z Med J** **128**:29–38, 2015
146. Langlois JA, Kegler SR, Butler JA, Gotsch KE, Johnson RL, Reichard AA, et al: Traumatic brain injury-related

- hospital discharges. Results from a 14-state surveillance system, 1997. **MMWR Surveill Summ** **52**:1–20, 2003
147. Lasry O, Dudley RW, Fuhrer R, Torrie J, Carlin R, Marcoux J: Traumatic brain injury in a rural indigenous population in Canada: a community-based approach to surveillance. **CMAJ Open** **4**:E249–E259, 2016
 148. Le Roux AA, Nadvi SS: Acute extradural haematoma in the elderly. **Br J Neurosurg** **21**:16–20, 2007
 149. Lee KS: Estimation of the incidence of head injury in Korea: an approximation based on national traffic accident statistics. **J Korean Med Sci** **16**:342–346, 2001
 150. Leibson CL, Brown AW, Ransom JE, Diehl NN, Perkins PK, Mandrekar J, et al: Incidence of traumatic brain injury across the full disease spectrum: a population-based medical record review study. **Epidemiology** **22**:836–844, 2011
 151. Li Y, Gu J, Zhou J, Xia X, Wang K, Zheng X, et al: The epidemiology of traumatic brain injury in civilian inpatients of Chinese Military Hospitals, 2001–2007. **Brain Inj** **29**:981–988, 2015
 152. Lin CM, Li CY: Assessment of medical resource utilization for Taiwanese children hospitalized for intracranial injuries. **Injury** **45**:690–695, 2014
 153. Maegele M, Engel D, Bouillon B, Lefering R, Fach H, Raun M, et al: Incidence and outcome of traumatic brain injury in an urban area in Western Europe over 10 years. **Eur Surg Res** **39**:372–379, 2007
 154. Maier D, Njoku I Jr, Schmutzhard E, Dharsee J, Doppler M, Härtl R, et al: Traumatic brain injury in a rural and an urban Tanzanian hospital—a comparative, retrospective analysis based on computed tomography. **World Neurosurg** **81**:478–482, 2014
 155. Majdan M, Mauritz W, Brazinova A, Rusnak M, Leitgeb J, Janciak I, et al: Severity and outcome of traumatic brain injuries (TBI) with different causes of injury. **Brain Inj** **25**:797–805, 2011
 156. Majdan M, Mauritz W, Rusnak M, Brazinova A, Rehorcikova V, Leitgeb J: Long-term trends and patterns of fatal traumatic brain injuries in the pediatric and adolescent population of Austria in 1980–2012: analysis of 33 years. **J Neurotrauma** **31**:1046–1055, 2014
 157. Majdan M, Rusnák M, Bražínová A, Mauritz W: Severity, causes and outcomes of traumatic brain injuries occurring at different locations: implications for prevention and public health. **Cent Eur J Public Health** **23**:142–148, 2015
 158. Marchio PS, Previgliano IJ, Goldini CE, Murillo-Cabezas F: [Head injury in Buenos Aires city: a prospective, population based, epidemiologic study.] **Neurocirugia (Astur)** **17**:14–22, 2006 (Span)
 159. Marlow R, Mytton J, Maconochie IK, Taylor H, Lyttle MD: Trends in admission and death rates due to paediatric head injury in England, 2000–2011. **Arch Dis Child** **100**:1136–1140, 2015
 160. Martins ET, Linhares MN, Sousa DS, Schroeder HK, Meinerz J, Rigo LA, et al: Mortality in severe traumatic brain injury: a multivariate analysis of 748 Brazilian patients from Florianópolis City. **J Trauma** **67**:85–90, 2009
 161. Masson F, Thicoipe M, Aye P, Mokni T, Senjean P, Schmitt V, et al: Epidemiology of severe brain injuries: a prospective population-based study. **J Trauma** **51**:481–489, 2001
 162. Mauritz W, Brazinova A, Majdan M, Leitgeb J: Epidemiology of traumatic brain injury in Austria. **Wien Klin Wochenschr** **126**:42–52, 2014
 163. Mauritz W, Brazinova A, Majdan M, Leitgeb J: Hospital admissions for traumatic brain injury of Austrian residents vs. of visitors to Austria. **Brain Inj** **28**:1295–1300, 2014
 164. Mauritz W, Brazinova A, Majdan M, Rehorcikova V, Leitgeb J: Deaths due to traumatic brain injury in Austria between 1980 and 2012. **Brain Inj** **28**:1096–1101, 2014
 165. McKinlay A, Grace RC, Horwood LJ, Fergusson DM, Ridder EM, MacFarlane MR: Prevalence of traumatic brain injury among children, adolescents and young adults: prospective evidence from a birth cohort. **Brain Inj** **22**:175–181, 2008
 166. Meehan WP III, Mannix R: Pediatric concussions in United States emergency departments in the years 2002 to 2006. **J Pediatr** **157**:889–893, 2010
 167. Melo JRT, de Santana DLP, Pereira JLB, Ribeiro TF: [Traumatic brain injury in children and adolescents at Salvador City, Bahia, Brazil.] **Arq Neuropsiquiatr** **64**:994–996, 2006 (Portuguese)
 168. Meng X, Shi B: Traumatic brain injury patients with a Glasgow Coma Scale score of ≤ 8 , cerebral edema, and/or a basal skull fracture are more susceptible to developing hyponatremia. **J Neurosurg Anesthesiol** **28**:21–26, 2016
 169. Miekisiak G, Czyz M, Tykocki T, Kaczmarczyk J, Zaluski R, Latka D: Traumatic brain injury in Poland from 2009–2012: a national study on incidence. **Brain Inj** **30**:79–82, 2016
 170. Mishra B, Sinha Mishra ND, Sukhla S, Sinha A: Epidemiological study of road traffic accident cases from Western Nepal. **Indian J Community Med** **35**:115–121, 2010
 171. Mitra B, Cameron P, Butt W: Population-based study of paediatric head injury. **J Paediatr Child Health** **43**:154–159, 2007
 172. Mitra B, Cameron PA, Butt W, Rosenfeld JV: Children or young adults? A population-based study on adolescent head injury. **ANZ J Surg** **76**:343–350, 2006
 173. Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, et al: Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. **Syst Rev** **4**:1–9, 2015
 174. Moore L, Evans D, Hameed SM, Yanchar NL, Stelfox HT, Simons R, et al: Mortality in Canadian trauma systems: a multicenter cohort study. **Ann Surg** **265**:212–217, 2017
 175. Moorin R, Miller TR, Hendrie D: Population-based incidence and 5-year survival for hospital-admitted traumatic brain and spinal cord injury, Western Australia, 2003–2008. **J Neurol** **261**:1726–1734, 2014
 176. Morisse E, Favarel-Garrigues JF, Couadau E, Mikulski M, Xavier L, Ryckwaert Y, et al: Incidence of hospital-admitted severe traumatic brain injury and in-hospital fatality rates in a Pacific Island country: a 5-year retrospective study. **Brain Inj** **28**:1436–1440, 2014
 177. Mosenthal AC, Lavery RF, Addis M, Kaul S, Ross S, Marburger R, et al: Isolated traumatic brain injury: age is an independent predictor of mortality and early outcome. **J Trauma** **52**:907–911, 2002
 178. Murray GD, Teasdale GM, Braakman R, Cohadon F, Dearden M, Iannotti F, et al: The European Brain Injury Consortium survey of head injuries. **Acta Neurochir (Wien)** **141**:223–236, 1999
 179. Muyembe VM, Suleman N: Head injuries at a Provincial General Hospital in Kenya. **East Afr Med J** **76**:200–205, 1999
 180. Myburgh JA, Cooper DJ, Finfer SR, Venkatesh B, Jones D, Higgins A, et al: Epidemiology and 12-month outcomes from traumatic brain injury in Australia and New Zealand. **J Trauma** **64**:854–862, 2008
 181. Myhre MC, Grøgaard JB, Dyb GA, Sandvik L, Nordhov M: Traumatic head injury in infants and toddlers. **Acta Paediatr** **96**:1159–1163, 2007
 182. Nakamura N, Yamaura A, Shigemori M, Ogawa T, Tokutomi T, Ono J, et al: Final report of the Japan Neurotrauma Data Bank project 1998–2001: 1,002 cases of traumatic brain injury. **Neurol Med Chir (Tokyo)** **46**:567–574, 2006
 183. Nigrovic LE, Lee LK, Hoyle J, Stanley RM, Gorelick MH,

- Miskin M, et al: Prevalence of clinically important traumatic brain injuries in children with minor blunt head trauma and isolated severe injury mechanisms. **Arch Pediatr Adolesc Med** **166**:356–361, 2012
184. Numminen HJ: The incidence of traumatic brain injury in an adult population—how to classify mild cases? **Eur J Neurol** **18**:460–464, 2011
185. Odebode TO: Age related pattern and outcome of head injury in indigenous Africa. **Niger J Clin Pract** **11**:265–269, 2008
186. Okyere-Dede EK, Nkalakata MC, Nkomo T, Hadley GP, Madiba TE: Paediatric head injuries in the KwaZulu-Natal Province of South Africa: a developing country perspective. **Trop Doct** **43**:1–4, 2013
187. Oluwole OSA: Incidence and risk factors of early post-traumatic seizures in Nigerians. **Brain Inj** **25**:980–988, 2011
188. Ovalle F Jr, Xu L, Pearson WS, Spelke B, Sugerman DE: Outcomes of pediatric severe traumatic brain injury patients treated in adult trauma centers with and without added qualifications in pediatrics - United States, 2009. **Inj Epidemiol** **1**:15, 2014
189. Pedersen K, Fahlstedt M, Jacobsson A, Kleiven S, von Holst H: A national survey of traumatic brain injuries admitted to hospitals in Sweden from 1987 to 2010. **Neuroepidemiology** **45**:20–27, 2015
190. Peeters W, van den Brande R, Polinder S, Brazinova A, Steyerberg EW, Lingsma HF, et al: Epidemiology of traumatic brain injury in Europe. **Acta Neurochir (Wien)** **157**:1683–1696, 2015
191. Peloso PM, von Holst H, Borg J: Mild traumatic brain injuries presenting to Swedish hospitals in 1987–2000. **J Rehabil Med (43 Suppl)**:22–27, 2004
192. Pérez K, Novoa AM, Santamariña-Rubio E, Narvaez Y, Arrufat V, Borrell C, et al: Incidence trends of traumatic spinal cord injury and traumatic brain injury in Spain, 2000–2009. **Accid Anal Prev** **46**:37–44, 2012
193. Phillips LA, Voaklander DC, Drul C, Kelly KD: The epidemiology of hospitalized head injury in British Columbia, Canada. **Can J Neurol Sci** **36**:605–611, 2009
194. Piatt JH Jr, Neff DA: Hospital care of childhood traumatic brain injury in the United States, 1997–2009: a neurosurgical perspective. **J Neurosurg Pediatr** **10**:257–267, 2012
195. Ponsford J, Willmott C, Rothwell A, Cameron P, Kelly AM, Nelms R, et al: Factors influencing outcome following mild traumatic brain injury in adults. **J Int Neuropsychol Soc** **6**:568–579, 2000
196. Pruthi N, Ashok M, Kumar VS, Jhavar K, Sampath S, Devi BI: Magnitude of pedestrian head injuries & fatalities in Bangalore, south India: a retrospective study from an apex neurotrauma center. **Indian J Med Res** **136**:1039–1043, 2012
197. Quayle KS, Powell EC, Mahajan P, Hoyle JD Jr, Nadel FM, Badawy MK, et al: Epidemiology of blunt head trauma in children in U.S. emergency departments. **N Engl J Med** **371**:1945–1947, 2014
198. Qureshi JS, Ohm R, Rajala H, Mabedi C, Sadr-Azodi O, Andréén-Sandberg Å, et al: Head injury triage in a sub-Saharan African urban population. **Int J Surg** **11**:265–269, 2013
199. Ramanathan DM, McWilliams N, Schatz P, Hillary FG: Epidemiological shifts in elderly traumatic brain injury: 18-year trends in Pennsylvania. **J Neurotrauma** **29**:1371–1378, 2012
200. Reid SR, Roesler JS, Gaichas AM, Tsai AK: The epidemiology of pediatric traumatic brain injury in Minnesota. **Arch Pediatr Adolesc Med** **155**:784–789, 2001
201. Rickels E, von Wild K, Wenzlaff P: Head injury in Germany: A population-based prospective study on epidemiology, causes, treatment and outcome of all degrees of head-injury severity in two distinct areas. **Brain Inj** **24**:1491–1504, 2010
202. Robertson BD, McConnel CE, Green S: Charges associated with pediatric head injuries: a five year retrospective review of 41 pediatric hospitals in the US. **J Inj Violence Res** **5**:51–60, 2013
203. Rochette LM, Conner KA, Smith GA: The contribution of traumatic brain injury to the medical and economic outcomes of motor vehicle-related injuries in Ohio. **J Safety Res** **40**:353–358, 2009
204. Rodríguez M: Predicting mortality from head injury: experience of Sancti Spiritus Province, Cuba. **MEDICC Rev** **15**:30–33, 2013
205. Rosso A, Brazinova A, Janciak I, Wilbacher I, Rusnak M, Mauritz W: Severe traumatic brain injury in Austria II: epidemiology of hospital admissions. **Wien Klin Wochenschr** **119**:29–34, 2007
206. Rubiano AM, Carney N, Chesnut R, Puyana JC: Global neurotrauma research challenges and opportunities. **Nature** **527**:S193–S197, 2015
207. Rus D, Chereches RM, Peek-Asa C, Marton-Vasarhely EO, Oprescu F, Brinzaniuc A, et al: Paediatric head injuries treated in a children's emergency department from Cluj-Napoca, Romania. **Int J Inj Contr Saf Promot** **23**:206–213, 2016
208. Rusnak M: Traumatic brain injury: giving voice to a silent epidemic. **Nat Rev Neurol** **9**:186–187, 2013
209. Rutland-Brown W, Langlois JA, Thomas KE, Xi YL: Incidence of traumatic brain injury in the United States, 2003. **J Head Trauma Rehabil** **21**:544–548, 2006
210. Ryu MS, Lee KS: Traumatic brain injury in childhood. **J Korean Child Neurol Soc** **14**:87–93, 2006
211. Ryu WHA, Feinstein A, Colantonio A, Streiner DL, Dawson DR: Early identification and incidence of mild TBI in Ontario. **Can J Neurol Sci** **36**:429–435, 2009
212. Saadat S, Akbari H, Khorramirouz R, Mofid R, Rahimi-Movaghar V: Determinants of mortality in patients with traumatic brain injury. **Ulus Travma Acil Cerrahi Derg** **18**:219–224, 2012
213. Sánchez AI, Krafty RT, Weiss HB, Rubiano AM, Peitzman AB, Puyana JC: Trends in survival and early functional outcomes from hospitalized severe adult traumatic brain injuries, Pennsylvania, 1998 to 2007. **J Head Trauma Rehabil** **27**:159–169, 2012
214. Schneier AJ, Shields BJ, Hostetler SG, Xiang H, Smith GA: Incidence of pediatric traumatic brain injury and associated hospital resource utilization in the United States. **Pediatrics** **118**:483–492, 2006
215. Scholten AC, Haagsma JA, Panneman MJM, van Beeck EF, Polinder S: Traumatic brain injury in the Netherlands: incidence, costs and disability-adjusted life years. **PLoS One** **9**:e110905, 2014
216. Seid M, Azazh A, Enqueselassie F, Yisma E: Injury characteristics and outcome of road traffic accident among victims at Adult Emergency Department of Tikur Anbessa specialized hospital, Addis Ababa, Ethiopia: a prospective hospital based study. **BMC Emerg Med** **15**:10, 2015
217. Selassie AW, Cao Y, Church EC, Saunders LL, Krause J: Accelerated death rate in population-based cohort of persons with traumatic brain injury. **J Head Trauma Rehabil** **29**:E8–E19, 2014
218. Selassie AW, Wilson DA, Pickelsimer EE, Voronca DC, Williams NR, Edwards JC: Incidence of sport-related traumatic brain injury and risk factors of severity: a population-based epidemiologic study. **Ann Epidemiol** **23**:750–756, 2013
219. Servadei F, Verlicchi A, Soldano F, Zanotti B, Piffer S: Descriptive epidemiology of head injury in Romagna and Trentino. Comparison between two geographically different Italian regions. **Neuroepidemiology** **21**:297–304, 2002

220. Sethi M, Heidenberg J, Wall SP, Ayoung-Chee P, Slaughter D, Levine DA, et al: Bicycle helmets are highly protective against traumatic brain injury within a dense urban setting. **Injury** **46**:2483–2490, 2015
221. Shao J, Zhu H, Yao H, Stallones L, Yeates K, Wheeler K, et al: Characteristics and trends of pediatric traumatic brain injuries treated at a large pediatric medical center in China, 2002–2011. **PLoS One** **7**:e51634–e51637, 2012
222. Shekhar C, Gupta LN, Premsagar IC, Sinha M, Kishore J: An epidemiological study of traumatic brain injury cases in a trauma centre of New Delhi (India). **J Emerg Trauma Shock** **8**:131–139, 2015
223. Shi HY, Hwang SL, Lee IC, Chen IT, Lee KT, Lin CL: Trends and outcome predictors after traumatic brain injury surgery: a nationwide population-based study in Taiwan. **J Neurosurg** **121**:1323–1330, 2014
224. Shi J, Xiang H, Wheeler K, Smith GA, Stallones L, Groner J, et al: Costs, mortality likelihood and outcomes of hospitalized US children with traumatic brain injuries. **Brain Inj** **23**:602–611, 2009
225. Shimoda K, Maeda T, Tado M, Yoshino A, Katayama Y, Bullock MR: Outcome and surgical management for geriatric traumatic brain injury: analysis of 888 cases registered in the Japan Neurotrauma Data Bank. **World Neurosurg** **82**:1300–1306, 2014
226. Shivaji T, Lee A, Dougall N, McMillan T, Stark C: The epidemiology of hospital treated traumatic brain injury in Scotland. **BMC Neurol** **14**:2, 2014
227. Shukri AA, Bersnev VP, Riabukha NP: [The epidemiology of brain injury and the organization of health care to victims in Aden (Yemen).] **Zh Vopr Neirokhir Im N N Burdenko**:40–42, 2006 (Russian)
228. Siman-Tov M, Radomislensky I, Knoller N, Bahouth H, Kessel B, Klein Y, et al: Incidence and injury characteristics of traumatic brain injury: comparison between children, adults and seniors in Israel. **Brain Inj** **30**:83–89, 2016
229. Slesak G, Inthalath S, Wilder-Smith A, Barennes H: Road traffic injuries in northern Laos: trends and risk factors of an underreported public health problem. **Trop Med Int Health** **20**:1578–1587, 2015
230. Solagberu BA, Osuoji RI, Ibrahim NA, Oludara MA, Balogun RA, Ajani AO, et al: Child pedestrian injury and fatality in a developing country. **Pediatr Surg Int** **30**:625–632, 2014
231. Song SY, Lee SK, Eom KS: Analysis of mortality and epidemiology in 2617 cases of traumatic brain injury: Korean Neuro-Trauma Data Bank System 2010–2014. **J Korean Neurosurg Soc** **59**:485–491, 2016
232. Sosin DM, Sniezek JE, Thurman DJ: Incidence of mild and moderate brain injury in the United States, 1991. **Brain Inj** **10**:47–54, 1996
233. Staton CA, Msilanga D, Kiwango G, Vissoci JR, de Andrade L, Lester R, et al: A prospective registry evaluating the epidemiology and clinical care of traumatic brain injury patients presenting to a regional referral hospital in Moshi, Tanzania: challenges and the way forward. **Int J Inj Contr Saf Promot** **24**:69–77, 2017
234. Steudel WI, Cortbus F, Schwerdtfeger K: Epidemiology and prevention of fatal head injuries in Germany—trends and the impact of the reunification. **Acta Neurochir (Wien)** **147**:231–242, 2005
235. Stocchetti N, Paternò R, Citerio G, Beretta L, Colombo A: Traumatic brain injury in an aging population. **J Neurotrauma** **29**:1119–1125, 2012
236. Styrke J, Stålnacke BM, Sojka P, Björnstig U: Traumatic brain injuries in a well-defined population: epidemiological aspects and severity. **J Neurotrauma** **24**:1425–1436, 2007
237. Sudlow A, McConnell N, Egan G, Jansen JO: Destination healthcare facility of patients with suspected traumatic brain injury in Scotland: analysis of pre-hospital data. **Injury** **44**:1237–1240, 2013
238. Sudlow CLM, Warlow CP: Comparing stroke incidence worldwide: what makes studies comparable? **Stroke** **27**:550–558, 1996
239. Suominen JS, Pakarinen MP, Kääriäinen S, Impinen A, Vartiainen E, Helenius I: In-hospital treated pediatric injuries are increasing in Finland—a population based study between 1997 and 2006. **Scand J Surg** **100**:129–135, 2011
240. Szarpak Ł, Madziąła M: Epidemiology of cranio-cerebral injuries in emergency medical services practice. **Pol Przegl Chir** **83**:646–651, 2011
241. Tabish A, Lone NA, Afzal WM, Salam A: The incidence and severity of injury in children hospitalised for traumatic brain injury in Kashmir. **Injury** **37**:410–415, 2006
242. Tait RJ, Anstey KJ, Butterworth P: Incidence of self-reported brain injury and the relationship with substance abuse: findings from a longitudinal community survey. **BMC Public Health** **10**:171, 2010
243. Tasker RC, Fleming TJ, Young AE, Morris KP, Parslow RC: Severe head injury in children: intensive care unit activity and mortality in England and Wales. **Br J Neurosurg** **25**:68–77, 2011
244. Tasker RC, Morris KP, Forsyth RJ, Hawley CA, Parslow RC: Severe head injury in children: emergency access to neurosurgery in the United Kingdom. **Emerg Med J** **23**:519–522, 2006
245. Tay EL, Lee SWH, Jamaluddin SF, Tam CL, Wong CP: The epidemiology of childhood brain injury in the state of Selangor and Federal Territory of Kuala Lumpur, Malaysia. **BMC Pediatr** **16**:56, 2016
246. Te Ao B, Tobias M, Ameratunga S, McPherson K, Theadom A, Dowell A, et al: Burden of traumatic brain injury in New Zealand: incidence, prevalence and disability-adjusted life years. **Neuroepidemiology** **44**:255–261, 2015
247. Tran TM, Fuller AT, Kiryabwire J, Mukasa J, Muhumuza M, Ssenyojo H, et al: Distribution and characteristics of severe traumatic brain injury at Mulago National Referral Hospital in Uganda. **World Neurosurg** **83**:269–277, 2015
248. Tsai WC, Chiu WT, Chiou HY, Choy CS, Hung CC, Tsai SH: Pediatric traumatic brain injuries in Taiwan: an 8-year study. **J Clin Neurosci** **11**:126–129, 2004
249. Twagirayezu E, Teteli R, Bonane A, Rugwizangoga E: Road traffic injuries at Kigali University Central Teaching Hospital, Rwanda. **East Cent Afr J Surg** **13**:73–76, 2008
250. Uche EO, Emejulu JK, Ekenze SO, Okorie E, Uche NJ: Neonatal head injury unrelated to birth trauma in South-East Nigeria. **Niger J Med** **22**:274–278, 2013
251. Udoh DO, Adeyemo AA: Traumatic brain injuries in children: a hospital-based study in Nigeria. **Afr J Paediatr Surg** **10**:154–159, 2013
252. Umerani MS, Abbas A, Sharif S: Traumatic brain injuries: experience from a tertiary care centre in Pakistan. **Turk Neurosurg** **24**:19–24, 2014
253. Vaishnavi S, Rao V, Fann JR: Neuropsychiatric problems after traumatic brain injury: unraveling the silent epidemic. **Psychosomatics** **50**:198–205, 2009
254. Ventsel G, Kolk A, Talvik I, Väli M, Vaikmaa M, Talvik T: The incidence of childhood traumatic brain injury in Tartu and Tartu County in Estonia. **Neuroepidemiology** **30**:20–24, 2008
255. von Elm E, Osterwalder JJ, Graber C, Schoettker P, Stocker R, Zangger P, et al: Severe traumatic brain injury in Switzerland - feasibility and first results of a cohort study. **Swiss Med Wkly** **138**:327–334, 2008
256. Wagner AK, Sasser HC, Hammond FM, Wierciszewski D, Alexander J: Intentional traumatic brain injury: epidemiol-

- ogy, risk factors, and associations with injury severity and mortality. **J Trauma** **49**:404–410, 2000
257. Walder B, Haller G, Rebetez MML, Delhumeau C, Bottequin E, Schoettker P, et al: Severe traumatic brain injury in a high-income country: an epidemiological study. **J Neurotrauma** **30**:1934–1942, 2013
258. Winqvist S, Lehtilahti M, Jokelainen J, Luukinen H, Hillbom M: Traumatic brain injuries in children and young adults: a birth cohort study from northern Finland. **Neuroepidemiology** **29**:136–142, 2007
259. Wong JC, Linn KA, Shinohara RT, Mateen FJ: Traumatic brain injury in Africa in 2050: a modeling study. **Eur J Neurol** **23**:382–386, 2016
260. World Health Organization: **World Health Statistics 2015**. (http://www.who.int/gho/publications/world_health_statistics/2015/en/) [Accessed January 10, 2018]
261. Yates PJ, Williams WH, Harris A, Round A, Jenkins R: An epidemiological study of head injuries in a UK population attending an emergency department. **J Neurol Neurosurg Psychiatry** **77**:699–701, 2006
262. Younis R, Younis M, Hamidi S, Musmar M, Mawson AR: Causes of traumatic brain injury in patients admitted to Rafidia, Al-Ittihad and the specialized Arab hospitals, Palestine, 2006–2007. **Brain Inj** **25**:282–291, 2011
263. Yousefzadeh Chabok S, Ramezani S, Kouchakinejad L, Saneei Z: Epidemiology of pediatric head trauma in Guilan. **Arch Trauma Res** **1**:19–22, 2012
264. Zhang AL, Sing DC, Rugg CM, Feeley BT, Senter C: The rise of concussions in the adolescent population. **Orthop J Sports Med** **4**:2325967116662458, 2016
265. Zhao YD, Wang W: Neurosurgical trauma in People's Republic of China. **World J Surg** **25**:1202–1204, 2001
266. Zhu H, Gao Q, Xia X, Xiang J, Yao H, Shao J: Clinically-important brain injury and CT findings in pediatric mild traumatic brain injuries: a prospective study in a Chinese reference hospital. **Int J Environ Res Public Health** **11**:3493–3506, 2014
267. Zubovic A, Shamdasani S, Fogarty EE, Moore D, Dowling F: Minor head injuries in children. **Ir Med J** **99**:121–123, 2006
268. Zuckerman SL, Yengo-Kahn AM, Buckley TA, Solomon GS, Sills AK, Kerr ZY: Predictors of postconcussion syndrome in collegiate student-athletes. **Neurosurg Focus** **40(4)**:E13, 2016

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