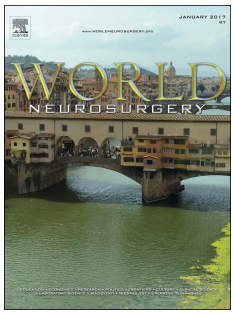
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Traumatic brain injury related paediatric mortality and morbidity in low- and middle-income countries: a systematic review

Soham Bandyopadhyay, Michal Kawka, Katya Marks, Georgia C. Richards, Elliott H. Taylor, Sanskrithi Sravanam, Tatjana Petrinic, Nqobile Thango, Anthony Figaji, Noel Peter, Kokila Lakhoo

PII: S1878-8750(21)00908-6

DOI: https://doi.org/10.1016/j.wneu.2021.06.077

Reference: WNEU 17419

To appear in: *World Neurosurgery*

Received Date: 27 April 2021

Revised Date: 12 June 2021

Accepted Date: 14 June 2021

Please cite this article as: Bandyopadhyay S, Kawka M, Marks K, Richards GC, Taylor EH, Sravanam S, Petrinic T, Thango N, Figaji A, Peter N, Lakhoo K, Traumatic brain injury related paediatric mortality and morbidity in low- and middle-income countries: a systematic review, *World Neurosurgery* (2021), doi: https://doi.org/10.1016/j.wneu.2021.06.077.

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Word count
Abstract: 250
Manuscript: 3286

Keywords
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Short Titles
Systematic review of pTBI in LMICs

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Traumatic brain injury related paediatric mortality and morbidity in low- and middle-income countries: a systematic review

Soham Bandyopadhyay[1], Michal Kawka[2], Katya Marks[3], Georgia C. Richards[4], Elliott H. Taylor[1], Sanskrithi Sravanam[5], Tatjana Petrinic[6], Nqobile Thango[7], Anthony Figaji[7], Noel Peter[1~], Kokila Lakhoo[1~]
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Abstract

Background:
The burden of paediatric traumatic brain injury (pTBI) in low-and-middle-income countries (LMICs) is unknown. To fill this gap, we conducted a review that aimed to characterise the causes of pTBI in LMICs, and their reported associated mortality and morbidity.

Methods:
A systematic review was conducted. MEDLINE, EMBASE, Global Health, and Global Index Medicus were searched from January 2000 to May 2020. Observational or experimental studies on pTBI of individuals aged between 0 and 16 years in LMICs were included. The causes of pTBI and morbidity data were descriptively analysed, and case fatality rates were calculated. PROSPERO ID: CRD42020171276.

Results:
136 studies were included. 57 studies were at high risk of bias. Of the remaining studies, there were reported 170224 cases of pTBI in 32 LMICs. The odds of having a pTBI was 1.8 times higher (95% CI: 1.6, 2.0) in males. The odds of a pTBI being mild was 4.4 times higher (95% CI: 1.9, 6.8) than a pTBI being moderate or severe. Road traffic accidents were the most common cause (n = 16275/41979, 39%) of pTBIs. On discharge, 24% of patients (n = 4385/17930) had a reduction in their normal mental or physical function. The median case fatality rate was 7.3 (IQR: 2.1 to 7.7).

Conclusions:
Less than a quarter (n= 32) of all LMICs have published high quality data on the volume and burden of pTBI. From the limited data available, young male children are at a high-risk of pTBIs in LMICs, particularly following road traffic accidents.

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Introduction

Childhood injuries are the leading cause of death in children above the age of one[1,2]. Among all the injury types, traumatic brain injury (TBI) – defined as "an alteration in brain function or other evidence of brain pathology, caused by an external force"[3] – is the most likely to result in death or permanent disability of a child[2]. In addition, TBI contributes to global mortality and morbidity more than any other traumatic insult[4]. This inordinately high number of person-years of life lost make paediatric TBI (pTBI) a public health priority.

There is an extensive library of literature on TBI[5]. However, most of these studies relate to TBI in the adult population. These studies cannot be extrapolated to children. Due to the different anatomy and physiology of their developing bodies, TBI occurring in children represent a different challenge to that presented by TBI in adults[2,6]. In addition to the consequences of TBI being markedly different between adults and children, the causes are likely to differ too. Therefore, not only is it critical for pTBI research to occur, but it is essential that the research is not biased by data from an adult population. High-income countries (HICs) have been particularly proficient at conducting such studies, and the limited data produced has been used to create guidelines[2,6].

However, another aspect of pTBI that has not been considered in current guidelines[2,6] is that the aetiology and the outcomes of pTBI may differ between paediatric populations across different countries, for example due to distinct healthcare systems or differing lifestyles[7]. This disparity is highlighted by the gulf between the healthcare systems of low- and middle-income countries (LMICs) and HICs[8]. Therefore, research pertaining to HICs may not reflect the burden of pTBI in LMICs. It is essential that the burden of pTBI in LMICs is characterised, as the majority of pTBI occurs in LMICs[9,10]. Understanding of the causes and outcomes of a disease in LMICs has been critical for the design and the implementation of effective prevention and treatment strategies locally, nationally, and internationally[11]. This underscores the need for such an understanding in pTBI.

To fill this gap, we conducted a systematic review that primarily aimed to characterise the causes of pTBI in LMICs, and their reported associated mortality and morbidity. The secondary aim was to determine the quality of pTBI mortality and morbidity data reported about LMICs. Insight into the consequences of pTBI in LMICs may prove vital for shaping public health policy, implementing prevention strategies, and justifying allocation of resources towards research, education, and rehabilitation. To achieve the Sustainable Development Goal of ending preventable deaths of children by 2030[12], the epidemic of pTBI in LMICs must not be neglected[10,13].

Methods

Search Strategy and Selection Criteria

A systematic review on the reported causes, mortality and morbidity of pTBI in LMICs was conducted as per the pre-registered protocol[14] (PROSPERO ID: CRD42020171276). For the purposes of this review, TBI is defined as "an alteration in brain function or other evidence of brain pathology, caused by an external force"[3], paediatric populations as individuals aged between 0 and 16 years[15] , and LMICs are those defined by the World Bank Criteria. Prior to the commencement of this study, all reviewers attended an online training and support session to ensure an accurate and standardised approach to the overall methodological process. The Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines[16] were used to report the findings (see Appendix S1).

The search was run on 12th May 2020. We searched four databases: MEDLINE, EMBASE, Global Health, and the World Health Organization (WHO) Global Index Medicus. The search strategy used terms related to TBI, paediatric populations and geographical areas classified as LMICs (see Appendix S2 for the complete search strategy). The retrieved studies were exported, and duplicates were removed. Due to changes in clinical classifications[17] and TBI definitions[3], we only included peer-reviewed studies published on or after January 2000. Given many LMICs have a national language other than English, we included all languages. Studies were eligible for inclusion if they were randomised controlled trials, non-randomised controlled trials, cohort studies, cross-sectional studies, epidemiological studies on incidence or prevalence, and case-controls studies. Estimates derived from modelling of other variables or extrapolations from other populations were excluded. Studies that did not state their methodology were also excluded. Case series and case reports were excluded.

Two reviewers independently screened the titles and abstracts based on the pre-defined inclusion and exclusion criteria. The full texts articles were retrieved and screened by two reviewers independently. Disagreements were resolved by mutual agreement. The reference lists of all included articles and previously excluded review

articles were scrutinised to locate additional relevant publications not identified during the database searches. Grey literature documents – such as reports published by the WHO – were examined to identify additional studies for inclusion.

Data extraction

A standardised data extraction form (see Appendix S3) was developed and piloted before its use. Data extraction was completed in duplicate by two reviewers independently. A third reviewer validated the data extracted and resolved any disagreements. We extracted publication characteristics, study design, setting, details of the included populations, types and causes of pTBI, deaths following pTBI, and morbidities secondary to pTBI (Table 1). If two or more studies had overlapping study populations and study periods, data points were extracted from all the studies in question and compared against one another. Where a data point was identical across all the studies, it was included. Where there was a disagreement between about the value of the same data point, only the data point extracted from the data source of the lowest risk of bias was included.

Table 1. Variables extracted from included studies.

Data Extracted	
Publication Characteristics	Title of Publication Language of Article Journal Name Year Published First Author Details (name & country of origin)
Study Design	Randomised controlled trials, non-randomised controlled trials, cohort studies, cross-sectional studies, incidence/ prevalence surveys, or case-controls studies Study Duration
Study Setting	Country Being Studied
Study Population	Age Range of Paediatric Study Population Sex of Paediatric Study Population Number of individuals in the Paediatric Study Population
Demographics of Paediatric TBI cases	Types of TBI (in accordance with ICD-10) Severity of TBI (categorised by the Glasgow Coma Scale)
Causes of Paediatric TBI	Patient falling, objecting falling on patient, sports injuries, natural disaster, injury from explosion or bullets, non-accidental injury, road traffic accidents, other or unspecified cause
Paediatric Deaths Following TBI	Number of deaths primarily due to TBI Number of death due to secondary complications of TBI Number of total deaths post TBI (all-cause mortality)
Paediatric Morbidities Secondary to TBI	Hospital admissions of paediatric TBI cases ICU admissions of paediatric TBI cases Mean length of hospital stay Number of paediatric TBI cases that required surgery Number of paediatric TBI cases that required CSF drainage or diversion Number of paediatric TBI cases that underwent intubation and mechanical ventilation Number of paediatric TBI cases that took anticonvulsants Number of paediatric TBI cases that required rehabilitation support Number of patients with psychiatric complications post-discharge Number of patients with disability post-discharge

Risk of bias assessment

Articles that had fewer than 50 individuals (or where the exact number was not stated) with pTBI within their sample population were automatically deemed to be at high-risk of bias. For the remaining articles (Table 2), two reviewers independently assessed the quality of each included study using the NIH NHLBI Quality Assessment Tool for Observational Cohort and Cross-sectional Studies[18]. Documents were graded as high (bias is highly likely due to essential errors), unclear (no essential deficiencies, but not all criteria are met), or low (bias is unlikely) risk of bias (Table 3). Any uncertainty was resolved through discussion among the reviewers.

Data analysis

Data from high-risk of bias studies were excluded from further analysis unless explicitly stated otherwise. Descriptive statistics are reported using percentages, means, medians, interquartile ranges (IQR), and ranges where appropriate. Deaths from pTBI as a proportion of all pTBI cases were calculated and expressed as a case fatality rate (CFR), which is the number of reported deaths per 100 cases of reported pTBI. Causes of pTBI were pooled. The severity of pTBI was categorised by utilising the Glasgow Coma Scale (GCS) of reported cases in the studies: severe TBI is classified as a GCS score of 3-8, moderate as 9-12 and mild as 13-15. Graphpad Prism 5 ™ statistical software was used.

Role of the funding source

There was no funding source for this study.

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Table 2. Characteristics of 83 included studies and their included participants, ordered alphabetically by study design. Only studies that had a sample population of greater than 50 individuals are listed.

Author, Year (Study ID)	Country(s) being studied	Inclusion Criteria	Number of paediatric TBI patients	Age range of paediatric TBI patients included	Number of male paediatric TBI patients (% of all paediatric TBI patients)	Study period (years)
Cross-sectional study						
Diaz-Olavarrieta 2011	Mexico	Children under 5, who suffered head trauma and were admitted to the National Paediatrics Institute in Mexico City	120	0 years to 5 years	79 (66)	2005
Hafiz 2011	Malaysia	Children aged 3 years old and below who were admitted to the Kuala Lumpur Hospital with diagnosis of moderate to severe traumatic brain injury from period of June 2007 to September 2009	153	0 years to 3 years	Not provided	2007 - 2009
Mahdian 2015	Iran	Traffic accident victims hospitalized more than 24 Hours in a Level III Trauma Center, Kashan County, Iran, during 2012-2013	103	0 years to 15 years	81 (79)	2012 - 2013
Melo 2004	Brazil	Victims with head injury assisted at the General Hospital of Bahia during 2001	76	0 years to 10 years	45 (59)	2001
Melo 2006	Brazil	All TBI victims, aged until 19 years admitted in a reference trauma center	213	0 years to 9 years	Not provided	2003 - 2004
Ortiz-Prado 2020	Ecuador	All hospital admissions and deaths due to traumatic brain injury registered in Ecuador from 2004 to 2016	38971	0 years to 14 years	23987 (62)	2004 - 2016
Prospective cohort						
Abdelaziz 2014	Egypt	Patients admitted to Alexandria Main University Hospital with head injuries after road traffic accidents during the Egyptian revolution period between January 2011 and July 2011.	55	6 months to 10 years	Not provided	2011
Adegoke 2011	Nigeria	All patients with injury who were admitted to the Children's Emergency Room at the Wesley Guild Hospital, Ilesa, Osun State, Nigeria, over a period of 2 years (1 June 2007 - 30 May 2009)	183	≤ 16 years (not defined)	Not provided	2007 - 2009
Arango 2008	Colombia	Children aged between 1 and 5 years, treated for TBI between June, 2003 and November, 2004, who were residents of the Aburra valley in north-	90	1 year to 5 years	58 (64)	2003 - 2004

		western Colombia, and did not suffer from other neurological problems				
Atwa 2017	Egypt	Patients, aged 18 years or less, who presented to the emergency department in the Suez Canal University Hospital, with head injuries, in the period from March 2014 to February 2015	70	3 months to 16 years	41 (59)	2014 - 2015
Bedry 2020	Ethiopia	Paediatric TBI cases, aged between 2 months and 14 years and that visited HUCSH from September 2017 to September 2018.	317	2 months to 14 years	218 (69)	2017 - 2018
Chaitanya 2018	India	All children < 16 years with TBI reporting to the neurosurgical emergency department at Aditya Birla Memorial Hospital	76	0 to 16 years	51 (67)	2015 - 2017
Djientcheu 2016	Cameroon	All the patients admitted for head injury in the emergency units of the selected hospitals in Cameroon.	232	0 years to 10 years	Not provided	2010 - 2011
Emejulu 2010	Nigeria	All patients with acute EDH managed in Nnamdi Azikiwe University Teaching Hospital from May 2006 to July 2013.	52	9 months to 15 years	13 (48)	2006 - 2007
Hassan 2017	Pakistan	Traumatic brain injury patients presenting to a teaching hospital of khyber pakhtunkhwa (Department of Neurosurgery, Lady Reading Hospital, Peshawar) from 1st September 2013 to 31st August 2014	264	0 years to 10 years	Not provided	2013 - 2014
Idowu 2014	Nigeria	Patients with traumatic brain (TBI) and spine injury (TSI) who presented at Lagos State University Teaching Hospital	203	0 years to 9 years	Not provided	2012 - 2013
Karmacharya 2015	Nepal	All children who presented with head injuries to the Neurosurgery Unit of Manipal teaching Hospital in Pokhara	287	0 years to 15 years	196 (68)	2014
Khan 2019	India	Patients presenting with TBI to a level I trauma center in India	211	0 years to 14 years	162 (77)	2016 - 2017
Kool 2012	Fiji	All fatal and hospitalised head injury patients recorded in the Fiji Injury Surveillance in Hospital system	75	0 years to 14 years	Not provided	2005 - 2006
Kuo 2017	Uganda	TBI patients presenting to Mulago National Referral Hospital (MNRH), Kampala, Uganda	93	1 year to 16 years	67 (72)	2016
Lafta 2019	Iraq	Paediatric age group from 1 year to 14 years old with surgically operated head trauma, in the period	52	1 year to 14 years	28 (54)	2014 - 2015

		from 1/10/2014 till 1/10/2015 in a neurosurgery hospital in Baghdad				
Li 2018	China	1656 Chinese children recruited between fall 2004 and spring 2005 from Jintan city	99	6 years to 12 years	52 (53)	2004 - 2013
Liao 2012	China	A random selection of 8291 TBI patients, 17 years or younger, diagnosed with TBI in 2005 to 2008 in Taiwan	6521	0 years to 14 years	Not provided	2005 - 2008
Liu 2013	China	1656 Chinese children recruited between fall 2004 and spring 2005 from Jintan city	167	6 years to 6 years	96 (57)	2004 - 2005
Mabiala-Babela 2010	Brazil	Infants aged 1–24 months admitted to the emergency department of the university hospital of Brazzaville (Congo) from 1st January 2007 to December 31, 2008	213	0 years to 9 years	Not provided	2003
Maia 2014	Brazil	Patients who suffered traumatic brain injuries (TBI) in the period from July 31, 2007 to August 1, 2008, and were seen at selected trauma units in Salvador, Bahia, Brazil	422	0 years to 15 years	Not provided	2007 - 2008
Masaeli 2019	Iran	Head trauma children who were referred to the emergency departments of Firouzgar and Besat Hospitals, Tehran, Iran, from September 2018 to May 2019	368	0 years to 6 years	Not provided	2018 - 2019
Mc Fie 2016	South Africa	South African youth rugby union players who played at the 2011 to 2014 South African Rugby Union Youth Week Tournaments.	108	0 years to 16 years	108 (100)	2011 -2014
Munakomi 2016	Nepal	Neurosurgical trauma patients who presented with mild-to-severe traumatic brain injury (TBI) from January 2013 to April 2014 at a tertiary care center in rural Nepal.	123	0 years to 10 years	Not provided	2013 - 2014
Nordon 2012	Brazil	Children who were admitted in the emergency service of Unidade Regional de Emergencia – Conjunto Hospitalar de Sorocaba due to traumatic brain injury	68	0 years to 16 years	Not provided	2010
Slaveykov 2019	Bulgaria	Children with head injury who presented to the University Hospital “Prof. Dr. Stoian Kirkovich”, Stara Zagora, Bulgaria, Department of Neurosurgery.	64	0 years to 15 years	Not provided	2016 - 2018
Solagberu 2014	Nigeria	Injured child pedestrians (≤15 years) who presented from 12 December 2011 to 11	108	0 years to 15 years	60 (56)	2011 - 2013

		December 2013 at the Surgical Emergency Room (SER) of the Lagos State University Teaching Hospital (LASUTH), Ikeja, Nigeria				
Tabish 2006	India	All children below the age of 15 with TBI who were admitted to the Accident & Emergency Department of Sher-e-Kashmir Institute of Medical Sciences, Srinagar (India)	1500	0 years to 15 years	903 (60)	2003
Thapa 2010	India	Patients with traumatic brain injury (TBI) (July 2007-2008) admitted after 24h of injury at All India Institute of Medical Sciences (AIIMS), Ansari Nagar, New Delhi 110029, India.	93	0 years to 10 years	Not provided	2007 - 2008
Umerani 2014	Pakistan	Patients presenting with head injury to the Accident and Emergency Department of a tertiary care centre in Pakistan	62	0 years to 10 years	41 (66)	2009 - 2011
Wani 2017	India	Patients with TBI, 18 years or less in age, managed in an Indian Department of Neurosurgery	294	0 years to 12 years	Not provided	2011 - 2013
Xing 2008	China	Traumatic brain injury patient in 77 hospitals in eastern China, 2004	1022	0 years to 14 years	Not provided	2004
Retrospective cohort						
Abdelgadir 2018	Uganda	All paediatric neurosurgical cases between 2012 and 2015 who were admitted at Mbarara Regional Referral Hospital (MRRH) in western Uganda.	257	2 months to 11 years	Not provided	2012 - 2015
Adam 2016	Ghana	All patients admitted into the Tamale Teaching Hospital, Ghana and diagnosed as having TBI	189	≤ 16 years (not defined)	68 (72)	2009 - 2012
Aras 2017	Turkey	Patients with head injury who were admitted to the Trauma and Emergency Surgery Department of Istanbul University, Istanbul School of Medicine, Istanbul, Turkey from January 1, 2014, through 31 December, 2014	323	0 years 10 15 years	Not provided	2014
Boniface 2017	Tanzania	Traumatic brain injury patients who attended Muhimbili Orthopedic Institute between January 2014 and June 2014	169	1 year to 15 years	Not provided	2014
Buitendag 2017	South Africa	All patients aged ≤18 years old who were admitted by the Pietermaritzburg Metropolitan Trauma Service (PMTS) with TBI between December 2012 and December 2016	563	≤ 16 years (not defined)	398 (71)	2012 - 2016
Cavalcanti 2014	Brazil	Child and adolescent victims of automobile accidents who died and had their forensic medical	83	0 year to 14 years	59 (71)	2008 -2011

		report kept in the Legal Medical Institute of Campina Grande, Brazil, between January 2008 and December 2011				
Chong 2017	China, Pakistan, Vietnam, India, Malaysia	Children <16 years old who presented within 24 hours of head injury and were admitted for observation or required a computed tomography of the brain from the emergency department at eight PATOS centres	438	0 years to 16 years	Not provided	2014 - 2015
De Almeida 2016	Brazil	All TBI cases in Brazil between 2008 and 2012 as collected through the website of the Information Technology Department of the Unified Health System (DATASUS) maintained by the Brazilian Ministry of Health	19180	0 years to 14 years	Not provided	2008 - 2012
Edwards 2014	Afghanistan and Iraq	Children with blast injury in Afghanistan and Iraq from 2002 to 2010 treated at US military treatment facilities	909	0 years to 14 years	Not provided	2005 - 2010
Egbohou 2019	Togo	0 to 15 years old admitted during the period from 1 January 2012 to 30 June 2018 at the ICU of SOUH of Lome	91	0 years to 15 years	61 (67)	2012 - 2018
Er 2017	Turkey	Patients who were injured in the Syrian Civil War and transferred to the emergency department at Antakya State Hospital between July 2013 and October 2014	156	≤ 16 years (not defined)	Not provided	2013 - 2014
Fakharian 2014	Iran	Patients under the age of two who were hospitalized for more than 24 hours between January 2004 and January 2010 in Iran	604	0 years to 2 years	343 (57)	2004 - 2010
Guillen-Pinto 2013	Peru	Traumatic brain injury (TEC) in children seen at the Cayetano Heredia National Hospital from 2004 to 2011	352	0 years to 14 years	202 (64)	2004 - 2011
Gupta 2017	Nepal	Patients aged less than 16 years with history of trauma from January 1st 2013 to 31st December 2013 who attended the Emergency Department in a Tertiary Care Center in Eastern Nepal	190	5 years to 10 years	Not provided	2013
Guzel 2007	Turkey	Patients who presented to the paediatric emergency unit in the Department of Child Health and Diseases Department, Edirne, Turkey with the complaint of falling	136	5 months to 13 years	Not provided	2003 - 2005
Hassen 2012	Tunisia	Children hospitalized for traumatic brain injury in	298	1 month to 15	Not provided	2007

		the Hospital of Child of Tunis during a 1-year period (2007)		years		
Hode 2016	Benin	All children from 0 to 16 years victims of cranial trauma admitted from July 2012 to December 2013 at National University Hospital Center in Cotonou (CNHU-HKM)	102	0 years to 15 years	Not provided	2012 - 2013
Ibrahim 2015	Nigeria	Non-accidental TBI in children starting from September 2008 to March, 2014 at Murtala Mohammad Specialist Hospital	109	0 years to 16 years	67 (61)	2008 - 2014
Iranmanesh 2009	Iran	Patients younger than 18-years-old admitted to the surgery ward of Ali-E-Bne-Abitaleb Hospital, Rafsanjan due to head trauma	247	0 years to 11 years	Not provided	2003- 2005
Isik 2011	Turkey	Patients younger than 14 years old with head injury, treated in the Neurosurgery Department of Samsun Mehmet Aydın Education and Research Hospital between January 2003 and June 2008	851	0 years to 14 years	550 (65)	2003 - 2008
Jagnoor 2012	India	Patients presenting with fall related injury at the Emergency Department of the Nehru Hospital, Chandigarh, India between March 2008 and February 2009	408	0 years to 14 years	Not provided	2008 - 2009
Jasper 2014	Nigeria	Patients that presented with head injury at the Accident and Emergency unit of the Jos University Teaching Hospital (JUTH), Jos, Nigeria with traumatic brain injury from February 2012 to January 2013	56	1 years to 10 years	Not provided	2012 - 2013
Ji 2016	China	Children with head-injuries across China as per the National Injury Surveillance System of China, 2014	42663	0 years to 14 years	Not provided	2014
Jianbo 2012	China	Hospitalized TBI patients (0–17 years of age) treated at the Wuhan Medical Care Center for Women and Children in China between 2002-2011.	4230	0 years to 15 years	2749 (65)	2002 - 2011
Klimo 2015	Iraq and Afghanistan	Children (<18 years old) in the Joint Theater Trauma Registry with isolated head injury (defined as an Abbreviated Injury Score Severity Code >3) and treated at a US combat support hospital in Iraq or Afghanistan (2004-2012)	354	0 years to 12 years	Not provided	2004 - 2012
Li 2015	China	Civilian inpatients of Chinese military hospitals	14178	0 years to 10	9416 (66)	2001 - 2007

		diagnosed with TBI between 2001-2007		years		
Li 2017	China	Children with TBI aged 0-17 years between 2001 and 2007 as retrieved from the Chinese Trauma Database	18922	0 years to 14 years	12791 (68)	2001 - 2007
Mukhida 2006	Nepal	Patients <or=18 years who presented to Tribhuvan University Teaching Hospital between April 1, 2001 and April 1, 2004 with acute neurological trauma and were subsequently admitted to hospital	235	0 years to 11 years	Not provided	2001 - 2004
Naidoo 2015	South Africa	Paediatric trauma patients (younger than 16) admitted to a level 1 trauma intensive care unit (TICU) at Inkosi Albert Luthuli Central Hospital, Durban, South Africa	112	0 years to 16 years	Not provided	2008 - 2012
Omerhodzic 2020	Bosnia and Herzegovina	Patients presenting with head injury to the Department of Neurosurgery of University Clinical Centre Sarajevo during the period 1 July 2006 – 30 June 2012	254	0 years to 10 years	Not provided	2006 - 2012
Peymani 2012	Iran	Fatal pedestrian accidents in Fars Province of Iran	140	0 years to 15 years	Not provided	2009 - 2011
Prasad 2015	India	Young children undergoing decompressive craniectomy (DC) for traumatic brain injury (TBI) at Jai Prakash Narayan Apex Trauma Centre, AlIMS,	71	0 years to 3 years	43 (61)	2008 - 2014
Saatian 2018	Iran	Patients with TBI during 2013 to 2016 in a single center in Hamedan, central Iran	2186	0 years to 10 years	1309 (60)	2013 - 2016
Satapathy 2016	India	Children <15 years with TBI at Department of Neurosurgery, S.C.B. Medical College, Cuttack, Odisha, India	147	0 years to 15 years	101 (69)	2012 - 2013
Sundet 2018	Malawi	All children aged ≤16 who were treated in the casualty department at the central hospital in Lilongwe, Malawi, between 1 January 2009 and 31 December 2015	2155	0 years to 16 years	Not provided	2009 - 2015
Suresh 2010	India	Children admitted with head injury due to TV fall in Kanchi Kamakoti CHILDS Trust Hospital, Nageswara Road, Nungambakkam, Chennai, Tamil Nadu during March 2007-February 2008	132	0 years to 16 years	Not provided	2007 - 2008
Tay 2016	Malaysia	All traumatic brain injury cases for children ages 0–19 included in the 2010 Malaysian National Trauma Database report	208	0 years to 14 years	Not provided	2010

Tokdemir 2009	Turkey	All cases patients to the emergency department of Firat University with suspected injury after involvement in a motor vehicle-related accident between January 2000 and January 2005.	211	0 years to 16 years	Not provided	2000 - 2005
Tunthanathip 2017	Thailand	Children, who were younger than 15 years old with TBI and presented to the Division of Neurosurgery, Department of Surgery, Faculty of Medicine, Songklanagarind Hospital, Prince of Songkla University, Songkhla, Thailand	948	1 month to 14 years	603 (64)	2004 - 2015
Udoh 2013	Nigeria	All paediatric patients with traumatic brain injury who presented to the University of Benin Teaching Hospital between October 2006 and September 2011	122	0 years to 16 years	61 (50)	2006 - 2011
Wang 2018	China	Patients who were children and adolescent who had traumatic skull fractures admitted to our university affiliated hospitals between January 2003 and December 2010.	316	0 years to 15 years	220 (70)	2003 - 2010
Waqas 2017	Pakistan	Children less than 3 years of age admitted to Aga Khan University Hospital with a head injury	109	0 years to 3 years	75 (69)	2009 -2012
Xia 2012	China	Children less than 5 years of age admitted to WMCCWC with a discharge diagnosis of traumatic brain injury from January 1, 2002 to December 31, 2011	3061	0 years to 5 years	1966 (64)	2002 - 2011
Yagmur 2016	Turkey	Preschool children deaths from TBI (from records of the Morgue Department of the Council of Forensic Medicine in Istanbul)	203	0 months to 60 months	117 (58)	2008 - 2012
Younis 2011	Palestine	Patients who were diagnosed with TBI and admitted to Rafidia, Al-Ittihad and the specialized Arab hospitals, Palestine in 2006 and 2007	95	0 years to 9 years	Not provided	2006 - 2007
Zhang 2019	China	Patients aged ≤17 years admitted to level 1 children's hospital located in Eastern China due to TBI between 1 January 2013 and 31 December 2015	830	0 years to 6 years	Not provided	2013 - 2015

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Table 3. Quality of each included study that had a sample population of more than 50 individuals with paediatric traumatic brain injury. Risk of bias assessed using the NIH NHLBI Quality Assessment Tool for Observational Cohort and Cross-sectional Studies[18]*. For the Study ID column, green denotes articles graded as low risk of bias, yellow denotes articles graded as unclear risk of bias, and red denotes articles graded as high risk of bias. Q1 - Was the research question or objective in this paper clearly stated?; Q2 – Was the study population clearly specified and defined?; Q3 – Was the participation rate of eligible persons at least 50%?; Q4 – Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?; Q5 – Was a sample size justification, power description, or variance and effect estimates provided?; Q6 – For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?; Q7 – Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?; Q8 – For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?; Q9 – Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?; Q10 – Was the exposure(s) assessed more than once over time?; Q11 – Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?; Q12 – Were the outcome assessors blinded to the exposure status of participants? Q13 – Was loss to follow-up after baseline 20% or less?; Q14 – Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?*

Author, Year (Study ID)	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14
Abdelaziz 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	NA	Yes	NA	Yes	Yes
Abdelgadir 2018	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Adam 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Adegoke 2011	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Arango 2008	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Aras 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Atwa 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Bedry 2020	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Boniface 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Buitendag 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Cavalcanti 2014	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Chaitanya 2018	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Chong 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
De Almeida 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Diaz-Olavarrieta 2011	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	NA	Yes	NA	Yes	Yes
Djientcheu 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Edwards 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Egbohou 2019	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Emejulu 2010	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes

Er 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Fakharian 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Guillen-Pinto 2013	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Gupta 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Guzel 2007	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Hafiz 2011	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Hassan 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Hassen 2012	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Hode 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Ibrahim 2015	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Idowu 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Iranmanesh 2009	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Isik 2011	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	NA	Yes	NA	Yes	Yes
Jagnoor 2012	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Jasper 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Ji 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Jianbo 2012	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Karmacharya 2015	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	NA	Yes	NA	Yes	Yes
Khan 2019	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Klimo 2015	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Kool 2012	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Kuo 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Lafta 2019	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	NA	Yes	NA	Yes	Yes
Li 2015	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Li 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Li 2018	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Liao 2012	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Liu 2013	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Mabiala-Babela 2010	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Mahdian 2015	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Maia 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Masaeli 2019	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes

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Mc Fie 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Melo 2004	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Melo 2006	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Mukhida 2006	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Munakomi 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Naidoo 2015	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Nordon 2012	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Omerhodzic 2020	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	NA	Yes	NA	Yes	Yes
Ortiz-Prado 2020	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Peymani 2012	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Prasad 2015	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Saatian 2018	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Satapathy 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Slaveykov 2019	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Solagberu 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Sundet 2018	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Suresh 2010	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Tabish 2006	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Tay 2016	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Thapa 2010	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Tokdemir 2009	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Tunthanathip 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Udoh 2013	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes
Umerani 2014	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	NA	Yes	NA	Yes	Yes
Wang 2018	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Wani 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Waqas 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	NA	Yes	NA	Yes	Yes
Xia 2012	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Xing 2008	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Yagmur 2016	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Younis 2011	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes
Zhang 2019	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	NA	Yes	NA	Yes	Yes

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Results

The database searches identified 3174 records with 1329 from MEDLINE, 1456 from EMBASE, 311 from Global Health, and 78 from WHO Global Index Medicus (Figure 1). After removing duplicates, and screening titles, abstracts, and full-texts, 136 studies were included: 122 from database searches, and 14 articles from the reference lists of included papers and excluded reviews (see Figure 1). Respectively 17, 62, and 57 studies were at low-risk, unclear-risk, and high risk of bias (Figure 1 and Table 3).

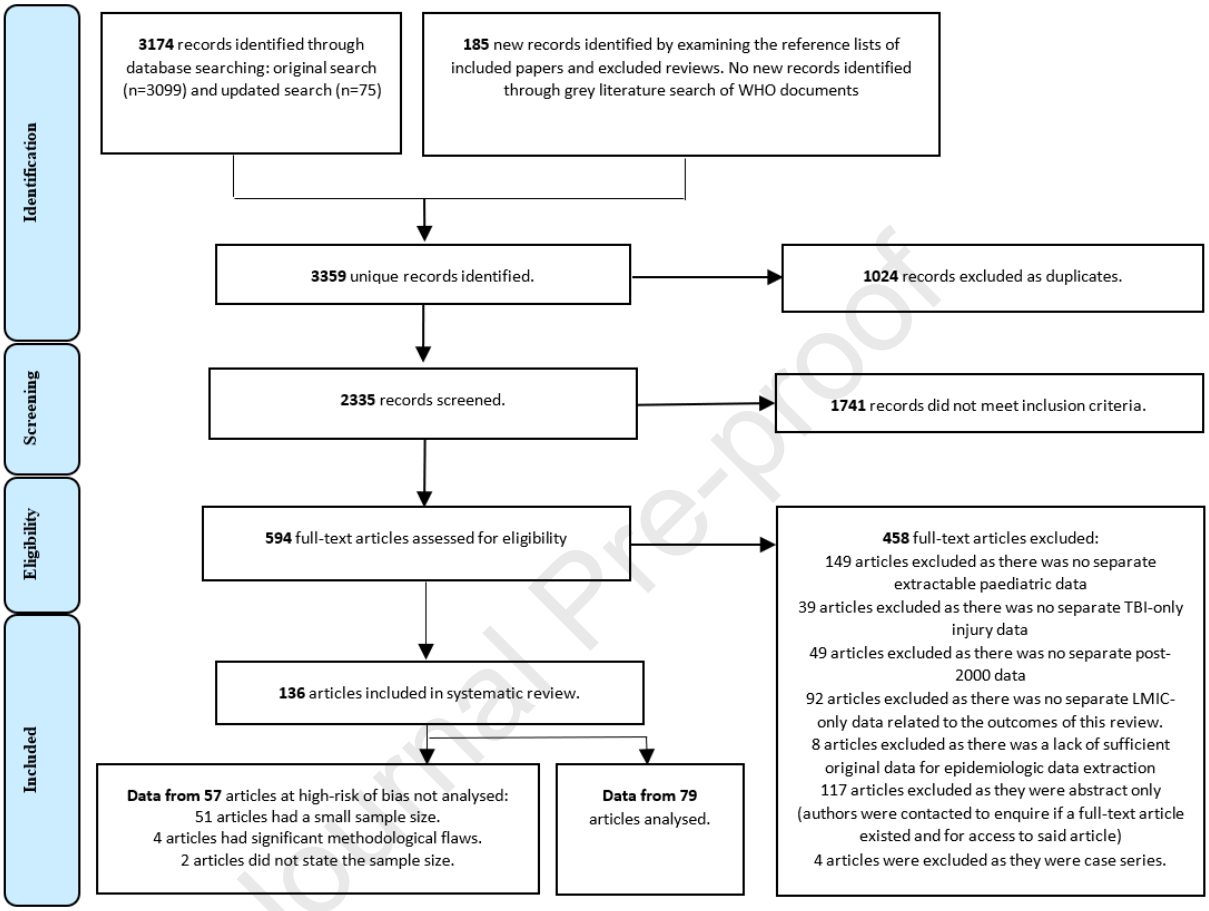


Figure 1. PRISMA flowchart of the source selection process

The included articles comprised data on approximately a quarter of all LMICs (n = 35/135, 26%) (Figure 2 and Appendix S4). All the data pertaining to three countries: Kenya, Indonesia, and Jordan were from articles judged to be at high-risk of bias. Most included studies (n = 125/136, 92%) used a cohort design with 35% prospective (n = 48/136) and 57% retrospective (n = 77/136) (Appendix S4). This pattern was maintained after excluding studies at high-risk of bias from analysis: 39% prospective cohort (n = 31/79), 53% retrospective cohort (n = 42/79), and 8% cross-sectional (n = 6/79). Among these articles, most studies (n = 53/79, 67%) included data from 2010 onwards (Table 2 and Appendix S4). China (n = 12/79, 15%), India (n = 9/79, 11%), and Nigeria (n = 7/79, 9%) were the countries of most interest among the articles that were not at high-risk of bias (Table 2). The number of pTBI patients in non-high-risk studies ranged widely (52 to 42663), with a median of 211 patients (IQR: 108 to 415). Five of these studies used population-based databases[19–23].

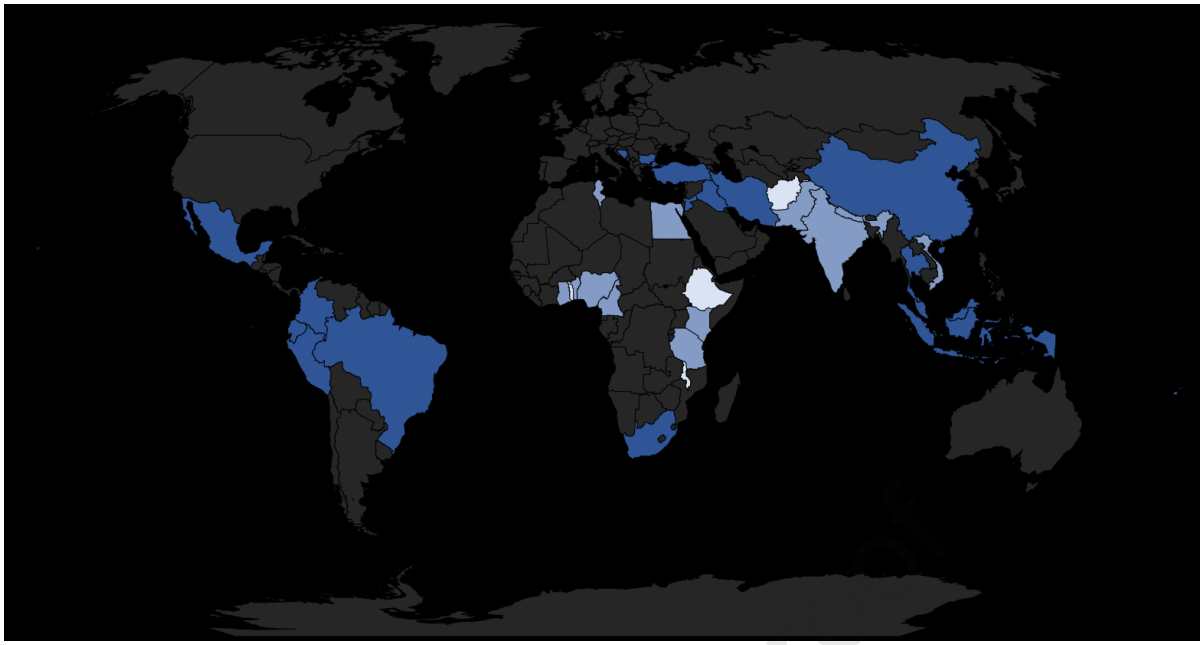


Figure 2. Data from the 136 included articles related to 35 low-and-middle income countries. White denotes low-income countries (n = 5). Light blue denotes lower-middle income countries (n = 13). Dark blue denotes upper-middle income countries (n = 17).

After excluding data from high-risk articles, there were 170224 cases of pTBI in 32 LMICs reported in the literature in the last 20 years. Where data on both male and female pTBI were available (n = 35/79, 42%), most studies (n = 33/35, 94%) reported more males than females having pTBI. The odds of having a pTBI was 1.8 times higher (95% CI: 1.6, 2.0) in males. Where present (n = 14/79, 18%), the reported mean age of the participants in the included studies ranged from 22.4 months[24] to 7.7 years[25]. 26 articles (n = 26/79, 33%) reported the GCS scores of their pTBI population (Table 4). However, two of these articles only included individuals with a pre-defined range of GCS scores[25,26]. Among the remaining 24 articles, the odds of a pTBI being mild was 4.4 times higher (95% CI: 1.9, 6.8) than a pTBI being moderate or severe. The odds of a pTBI being moderate was 1.8 times higher (95% CI: 1.1, 2.5) than a pTBI being severe. An additional 14 studies at a high-risk of bias also reported the GCS scores of their pTBI population (Appendix S5).

Table 4 – Paediatric patients with mild, moderate, or severe traumatic brain injury (TBI) as categorised by the Glasgow Coma Scale (GCS) in 26 studies with available data of the 79 included studies that were not at high-risk of bias. Two articles that only included individuals with a pre-defined range of GCS scores are shaded in red.

Author, Year (Study ID)	Country(s) being studied	Total number of paediatric patients with TBI by severity			Total number of paediatric patients with TBI
		Mild	Moderate	Severe	
Abdelaziz 2014	Egypt	43	10	2	55
Abdelgadir 2018	Uganda	160	37	60	257
Atwa 2017	Egypt	57	9	4	70
Bedry 2020	Ethiopia	231	61	25	317
Buitendag 2017	South Africa	454	67	42	563
Chaitanya 2018	India	46	11	19	76
Diaz-Olavarrieta 2011	Mexico	73	15	12	120
Egbohou 2019	Togo			91	91
Emejulu 2010	Nigeria	31	7	14	52
Guillen-Pinto 2013	Peru			16	352
Hassen 2012	Tunisia	276	6	16	298
Hode 2016	Benin	55	35	12	102

Isik 2011	Turkey	630	187	34	851
Karmacharya 2015	Nepal	218	60	9	287
Khan 2019	India	155	28	28	211
Kuo 2017	Uganda	46	31	16	93
Lafta 2019	Iraq	31	13	8	52
Li 2018	China	99			99
Munakomi 2016	Nepal	110	8	5	123
Nordon 2012	Brazil	18	1	2	68
Omerhodzic 2020	Bosnia and Herzegovina	213	26	15	254
Satapathy 2016	India	83	43	21	147
Solagberu 2014	Nigeria	40	33	35	108
Sundet 2018	Malawi	2086	17	52	2155
Tunthanathip 2017	Thailand	800	71	77	948
Udoh 2013	Nigeria	35	36	51	122
	Totals (%)	**5990 (76)**	**812 (10)**	**666 (8)**	**7871 (100)**

The causes of pTBI were reported in 27% of included cases (n = 45504/ 170224, 27%). Several of these studies (n = 7/79, 9%) were at risk of bias for this outcome due to one of their inclusion criteria being a cause of pTBI, for example road traffic accidents[27] or falls[28]. After excluding these studies, a cause of pTBI was reported in 25% of cases (n = 41979/ 166644, 25%). Road traffic accidents were the most common cause (n = 16275/41979, 39%) of pTBIs, followed by other or unspecified causes (n = 10498/43083, 25%), and falls (n = 10375/41979, 25%) (Figure 3). In cases of pTBI following road traffic accidents, pedestrians were the largest demographic group of children across all but two studies[29,30].

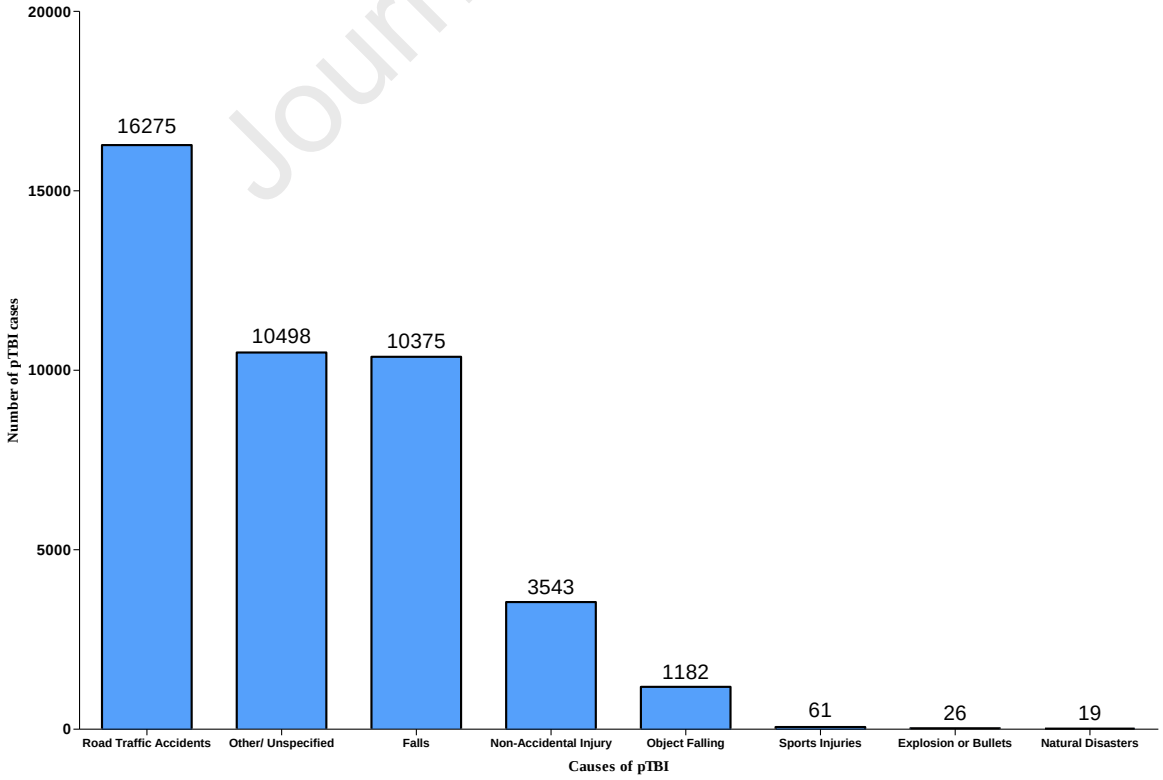


Figure 3. Causes of paediatric traumatic brain injury (pTBI) in 41979 of 166644 (25 %) included cases, in 32 low- and middle- income countries after high-risk of bias studies were removed.

27 studies (n = 27/79, 34%) reported the proportion of pTBI cases that were admitted to hospital: 43900 cases in total (n = 43900/44184, 99%). Six studies (n= 6/79, 8%) reported on the proportion of patients that were admitted into an intensive care unit (ICU): 256 in total (n = 256/1278, 20%). 17 studies (n = 17/79, 22%) documented the proportion of pTBI patients that underwent surgery: 1382 in total (n = 1382/ 5137, 27%). Patients' mean length of stay in hospital ranged from 1.7 days[29] to 13.45 days[31]. 15 studies (n = 15/79, 19%) reported on any reduction in normal function post-discharge in pTBI patients. A sum of 4360 (n = 4385/17930, 24%) patients were reported to have had a reduction in normal function (excluding death). Nine of these studies (n =9/15, 60%) used the Glasgow Outcome Scale (GOS)[32] or a proxy of the GOS classifications[33] (GOS 5 - good recovery, GOS 4 - moderate disability, GOS 3 - severe disability, GOS 2 - vegetative state, or GOS 1 - death) to describe the outcomes of pTBI patients. All 9 studies reported patients' GOS at discharge. Of the pTBI patients, 152 patients were GOS 4 (n = 152/2846, 5%), 50 patients were GOS 3 (n = 50/2846, 2%), and 23 patients were GOS 2 (n = 23/2846, 1%) at discharge (Figure 4). This pattern of findings, where patients were more likely to have moderate disability rather than severe disability or be in a vegetative state was replicated across all nine studies. Three of the nine studies also reported on patient outcomes between 3 to 6 months following discharge[34–36]. The six papers that did not use the GOS to report outcomes commented on the fact that post-discharge, patients did have neurological deficits but did not quantify the extent of disability from these neurological deficits.

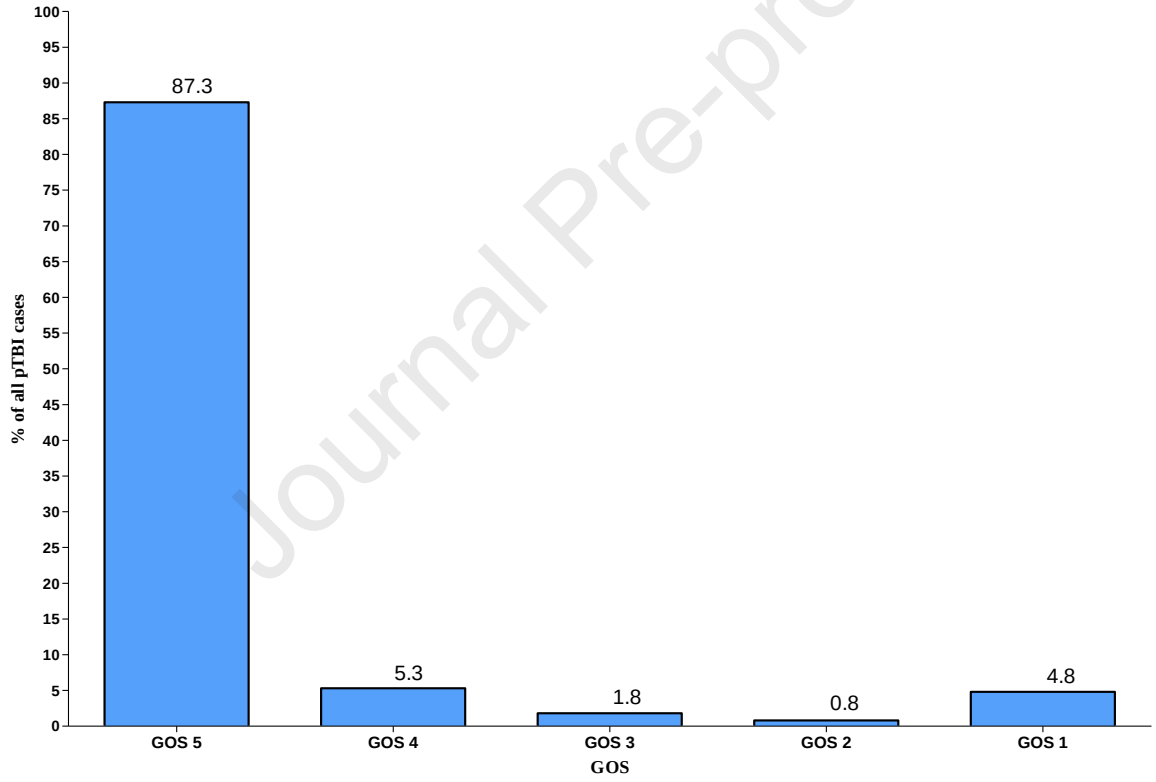


Figure 4. Combined Glasgow Outcome Scores (GOS) of patients that were reported in 9 included papers. The papers included data on 2846 paediatric traumatic brain injury (pTBI) patients. GOS 5 - good recovery, GOS 4- moderate disability, GOS 3 - severe disability, GOS 2 - vegetative state, or GOS 1 - death

Of the 79 studies that were not at high-risk of bias, 43% (n = 34/79) reported on the number of children who died post-TBI. There were 1480 deaths (n = 1480/ 65241, 2%) recorded. The CFR of a study ranged from 0.3 to 47.5 with a median of 7.3 (IQR: 2.1 to 7.7) (Table 5). Of the five studies with more than 1000 pTBI patients, the CFR ranged from 0.3 to 2.1[22,31,37–39]; these studies were conducted in Brazil, China, and Iran. The CFR of a country ranged from 1.7 to 47.5 with a median of 4.2 (IQR: 2.9 to 8.1). An additional 18 studies at a high-risk of bias also reported on all-cause pTBI mortality (Appendix S6).

Table 5. Paediatric traumatic brain injury (TBI) mortality as reported in 54 studies with available data of the 79 included studies that were not at high-risk of bias.

Author, Year (Study ID)	Country(s) being studied	Total number of paediatric TBI patients within study population	Total number of paediatric patients that died from the TBI	Total number of paediatric patients that died from secondary consequences of TBI	All-cause paediatric TBI mortality	Case Fatality Ratio (CFR)	Aggregate Country CFR
Hode 2016	Benin	102	11		11	10.8	10.8
Omerhodzic 2020	Bosnia and Herzegovina	254			6	2.4	2.4
De Almeida 2016	Brazil	19,180			395	2.1	2.1
Xia 2012	China	3061			8	0.3	1.9
Zhang 2019	China	830			5	0.6	
Li 2017	China	18922			381	2.0	
Li 2015	China	14178			296	2.1	
Arango 2008	Colombia	90	3		3	3.3	3.3
Bedry 2020	Ethiopia	317			10	3.2	3.2
Kool 2012	Fiji	75			6	8	8
Chaitanya 2018	India	76			4	5.3	6.5
Khan 2019	India	211			13	6.2	
Satapathy 2016	India	147		7	11	7.5	
Fakharian 2014	Iran	604			5	0.8	1.7
Saatian 2018	Iran	2186			30	1.4	
Iranmanesh 2009	Iran	247	16		16	6.5	
Lafta 2019	Iraq	52	5		5	9.6	9.6
Diaz-Olavarrieta 2011	Mexico	120			6	5	5

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Karmacharya 2015	Nepal	287		4	8	2.8	2.9
Munakomi 2016	Nepal	123			4	3.3	
Ibrahim 2015	Nigeria	109	6		6	5.5	8.1
Adegoke 2011	Nigeria	183			14	7.7	
Emejulu 2010	Nigeria	52			8	15.4	
Chong 2017	Pakistan	101			48	47.5	47.5
Guillen-Pinto 2013	Peru	352			16	4.5	4.5
Buitendag 2017	South Africa	563	9		9	1.6	4.7
Naidoo 2015	South Africa	112	18		23	20.5	
Boniface 2017	Tanzania	169			5	3.0	3.0
Tunthanathip 2017	Thailand	948			30	3.2	3.2
Egbohou 2019	Togo	91	19	10	29	31.9	31.9
Hassen 2012	Tunisia	298	6		6	2.0	2.0
Isik 2011	Turkey	851	33		33	3.9	3.9
Kuo 2017	Uganda	93	4		4	4.3	8.6
Abdelgadir 2018	Uganda	257			26	10.1	
Total		**65241**	**130**	**21**	**1480**	**2.3**	

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Discussion

Our systematic review summarises the published literature on the causes, mortality, and morbidity of pTBI in LMICs. Less than one-quarter of LMICs have published data that is not at a high risk of bias on the volume and burden of pTBI in their country. The commonest cited causes of pTBI included road traffic accidents and falls. On average, there were 7.3 deaths per 100 cases of pTBI. Of those who survived, nearly one-quarter had a reduction from normal function on discharge. The reported mean age of children with pTBI in included studies ranged from 22.4 months[24] to 7.7 years[25]. It was far more common for these children to have a mild pTBI rather than moderate or severe pTBI. Male children were 1.8 times as likely as female children to have pTBI.

Our finding that pTBI is more likely to occur in the formative years of childhood in LMICs is in contrast to studies from the USA, where paediatric patients with TBI are mostly in their mid to late teens[40,41]. This has implications for lifetime spending on healthcare costs, as families in LMICs may be paying for management and rehabilitation from an earlier point in their child's life due to injuries occurring at a younger age. This could exacerbate the number of individuals facing catastrophic expenditure for healthcare[42]. In addition, TBI at an earlier stage of life has developmental consequences[43]. pTBI is associated with an increased risk of behavioural disorders and subsequent criminal activity[44]. This holds true even for children that have suffered mild pTBI[45]. Preventing pTBI would reduce the burden on community resources aimed at promoting recovery and rehabilitation, as a sizeable minority of participants in our included studies had ongoing neurological deficits. This is particularly concerning given TBI patients often retain these disabling symptoms several months after injury[46,47].

There are also implications of our finding that pTBI is more likely to occur in males than females. This finding could be explained by previous research that has shown that parents are less likely to restrain the exploratory behaviour of male children than female children, even if said behaviour poses an injury risk[48]. Female children are more likely to be supervised by someone who might protect them from injury[49], as male children are given more freedom to roam further from their home and be without adult supervision[50,51]. Male children are also more likely to engage in risky behaviour[50]. Thus, there is a need for targeted injury prevention campaigns that aim to ameliorate situations that may provoke risk taking behaviour[52] and reduce risk in situations that children find themselves in. Current campaigns focussing on sports[53] are not targeted interventions for LMICs, as sports injuries are a minor cause of pTBI in LMICs, albeit they are responsible for almost a fifth of all pTBIs in HICs[54]. Campaigns must be specific to LMIC causes of pTBI, which are primarily road traffic accidents and falls.

Our finding that most pTBIs caused by road traffic accidents are in child pedestrians is in contrast to findings in HICs - for example Australia[55], Europe[56], and North America[57] – where pTBI caused by road traffic accidents are largely found in vehicle occupants. Therefore, a targeted approach to reduce the incidence of pTBI in LMICs could be creating road safety resources for children, building sidewalks – and therefore making clearly defined roads –, increasing traffic lights, creating protected playgrounds, and providing children with bright clothing (fluorescent clothes for the day and reflective clothes for the night). This would need to be accompanied with a focus on road safety in traffic laws, and enforcement of said legislature[58].Similarly, pTBI from falls could be reduced by improving regulations on buildings, for example legislating for small gaps between balcony rails or a minimum height of a window from the floor[59].

Our findings likely under-represent the true burden of pTBI in LMICs, as most LMICs do not have published data on the volume of pTBI in their country and the disability associated with it[60,61]. Of the LMICs that do have published data on this topic, the data typically pertains to a few centres and study populations that are not fully representative of the general paediatric population. Consequently, our findings could be biased. For instance, our finding of male children being more likely to have a pTBI could be biased by females having fewer complications after a TBI[62] or being less likely to be taken to hospital[63]; thereby female children are less likely to be captured in studies that mainly focus on hospital populations. Similarly, the differences between LMICs and HICs could be explained by the different demographic profile of HICs compared to LMICs[64].

The lack of systematic reporting of all pTBIs and deaths due to pTBIs makes it difficult to effectively plan management strategies across LMICs and within most LMICs. This issue could be improved with the establishment of registry systems for patients with TBI worldwide[59]. This focussing of resources on injury epidemiology data would improve the accuracy of future epidemiological assessments of TBI. Future studies of pTBI should assess the role of socioeconomic status in determining the likelihood for pTBI, as this has relevance for prevention and rehabilitation. There is equally a need to examine if assessments of children are being carried out post discharge, as only a minority of studies reported on outcomes at discharge, and even

fewer reported on follow-up outcomes. This is important as whilst our study finds that most pTBI cases are mild, it is unclear whether the disabling effects of mild TBI can translate into economic, societal, and quality of life detriments. There is a need for data on long-term neurological and psychological sequelae to properly understand the extent of disabilities from pTBI. This data will allow the true financial burden of pTBI on families and wider society to be calculated, and a standardised prospectively recorded dataset will also allow for better analysis of the effectiveness of interventions.

Conclusions

This systematic review identifies key insights about pTBI in LMICs and begins to quantify the scope of the problem. One such insight is that children with pTBI in LMICs are of a young age, which has developmental, economical, and societal consequences. A second key insight is the fact that more males than females have TBI, and the need to identify the biopsychosocial mechanisms behind this difference. A third insight is the fact that pedestrians are the at-risk group of children for pTBI following road traffic accidents in LMICs. However, the limitations of the included studies highlight that more data is required to determine the true mortality and morbidity from pTBI in LMICs. For this data to be collected, it is essential that registry systems for patients with TBI are created worldwide. This extra data will be critical for country-specific analysis and the design of national policy.

Declarations

Consent for publication

All authors have approved the final manuscript and are willing to take responsibility for appropriate portions of the content.

Competing interests

GCR is financially supported by the National Institute of Health Research (NIHR) School for Primary Care Research (SPCR), the Naji Foundation, and the Rotary Foundation. All other authors declare no competing interests.

Funding

This research has received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' contributions

KL is the guarantor. SB and KL conceived the project. SB, TP, and KL contributed equally to the design of the project. SB, MK, KM, SS, and EHT contributed to the screening of data. SB, MK, KM, and SS contributed to the extraction of data. The first draft of the manuscript was written by SB. GCR, KL, AF, TP, MK, KM, EHT, NT, SS and NP critically reviewed and edited the manuscript. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Appendices

Appendix S1: PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	3
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	3-4
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	4
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	30-35
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	3-4
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	4
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	4
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was	14-16

		done at the study or outcome level), and how this information is to be used in any data synthesis.	
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	5
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	5
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	4, 14-16
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	5
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	17
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	6-13
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	14-16
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	6-13, 17-22
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	17-22
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	14-16
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	18-22
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	23
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	23-24
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	24
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	24

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Appendix S2: Search Strategy Executed

MEDLINE (1946-present):
1 exp BRAIN INJURIES,TRAUMATIC/
2 "traumatic brain injur* ".ab,kw,ti.
3 (TBI* or mTBI*).ab,kw,ti.
4 "head trauma* ".ab,kw,ti.
5 "head injur* ".ab,kw,ti.
6 "brain trauma* ".ab,kw,ti.
7 "acquired brain injur* ".ab,kw,ti.
8 (brain and concussion*).ab,kw,ti.
9 (brain and concussive).ab,kw,ti.
10 (Head and concussion*).ab,kw,ti.
11 (head and concussive).ab,kw,ti.
12 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13 exp DEVELOPING COUNTRIES/
14 "developing countr* ".ab,kw,ti.
15 "developing world* ".ab,kw,ti.
16 "LMIC*".ab,kw,ti.
17 "low* income* ".ab,kw,ti.
18 "middle income".ab,kw,ti.
19 "resource poor".ab,kw,ti.
20 "resource limited".ab,kw,ti.
21 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20
22 12 and 21
23 (pediatric* or paediatric* or child or children or infant* or neonat* or newborn* or adolescen*).ab,kw,ti.
24 22 and 23
25 limit 22 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)")
26 24 or 25
27 exp AFRICA/
28 Africa.ab,kw,ti.
29 (Algeria* or Angola* or Benin or Botswana* or Burkina or Burundi* or "Cabo Verde" or "Cape Verde" or Cameroon* or "Central African Republic" or Chad or Comoros or Congo* or "Cote d'Ivoire" or Djibouti or Egypt* or Guinea* or Eritrea* or Eswatini or Swaziland or Ethiopia* or Gabon or Gambia* or Ghana* or Kenya* or Lesotho or Liberia* or Libya* or Madagascar or Malawi* or Mali or Mauritania* or Mauritius or Morocc* or Mozambique or Namibia* or Niger or Nigeria* or Rwanda* or "Sao Tome and Principe" or Senegal* or Seychelles or "Sierra Leone" or Somalia or Sudan* or Tanzania* or Togo or Tunisia* or Uganda* or Zambia* or Zimbabwe* or Southafrica* or Maghreb*).ab,kw,ti.
30 (Sahara* or SubSahara*).ab,kw,ti.
31 27 or 28 or 29 or 30
32 12 and 31
33 23 and 32
34 limit 32 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)")
35 33 or 34
36 exp ASIA/
37 exp FAR EAST/
38 exp ASIA, CENTRAL/
39 exp ASIA, SOUTH/
40 exp ASIA, SOUTHEASTERN/
41 exp ASIA, WESTERN/
42 exp MIDDLE EAST/
43 exp TRANSCAUCASIA/
44 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43
45 JAPAN/ or SINGAPORE/ or TAIWAN/ or REPUBLIC OF KOREA/ or BAHRAIN/ or ISRAEL/ or KUWAIT/ or QATAR/ or SAUDI ARABIA/ or UNITED ARAB EMIRATES/
46 44 not 45
47 (Afghan* or Armenia* or Azerbaijan* or Bangladesh* or Bhutan* or Cambodia* or China or Chinese or "North Korea*" or "People* Republic of Korea" or Georgia* or India or Indian or Indonesia* or Iran* or Iraq* or Jordan* or Kazakhstan* or Kyrgyz* or Laos or Lao or Leban* or Malay* or Maldives or Mongolia* or

Myanmar or Burm* or Nepal* or Pakistan* or Philippines or "Sri Lanka*" or Syria* or Tajik* or Thailand or Thai or Turkey or Turkish or Turkmen* or Uzbek* or Vietnam* or Gaza or "West Bank" or Palestin* or Yemen*).ab,kw,ti.
48 46 or 47
49 12 and 48
50 23 and 49
51 limit 49 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)")
52 50 or 51
53 exp LATIN AMERICA/
54 exp SOUTH AMERICA/
55 exp CENTRAL AMERICA/
56 exp CARIBBEAN REGION/
57 MEXICO/
58 53 or 54 or 55 or 56 or 57
59 (Argentin* or Belize or Bolivia* or Brazil* or Colombia* or Cuba* or Chile* or "Costa Rica*" or Dominica* or Ecuador* or Salvador* or Grenada* or Guatemala* or Guyana* or Haiti* or Hondura* or Jamaica* or Mexico or Mexican* or Nicaragua* or Paraguay* or Peru or Peruvian* or "St* Lucia*" or "St* Vincent" or Suriname or Uruguay* or Venezuela*).ab,kw,ti.
60 58 or 59
61 12 and 60
62 23 and 61
63 limit 61 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)")
64 62 or 63
65 exp PACIFIC ISLANDS/
66 exp POLYNESIA/
67 exp MELANESIA/
68 exp MICRONESIA/
69 65 or 66 or 67 or 68
70 AUSTRALIA/ or SOUTH AUSTRALIA/ or WESTERN AUSTRALIA/ or NEW ZEALAND/ or HAWAII/ or NEW CALEDONIA/
71 69 not 70
72 (Samoa* or Fiji* or Kiribati* or "Marshall Island*" or Micronesia* or Nauru* or "Papua New" or Polynesia* or "Solomon Island*" or "Timor Leste" or Tonga* or Tuvalu*
or Vanuatu*).ab,kw,ti.
73 71 or 72
74 12 and 73
75 23 and 74
76 limit 74 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)")
77 75 or 76
78 exp RUSSIA/
79 ALBANIA/ or "BOSNIA AND HERZEGOVINA"/ or BELARUS/ or BULGARIA/ or KOSOVO/ or MOLDOVA/ or MONTENEGRO/ or "REPUBLIC OF NORTH MACEDONIA"/ or ROMANIA/ or SERBIA/ or UKRAINE/
80 (Russia* or Albania* or Bosnia* or Belarus* or Bulgaria* or Kosovo or Kosova* or Moldova* or Montenegr* or "North Macedonia*" or Romania* or Serbia* or Ukrain*).ab,kw,ti.
81 78 or 79 or 80
82 12 and 81
83 23 and 82
84 limit 82 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)")
85 83 or 84
86 26 or 35 or 52 or 64 or 77 or 85
87 limit 86 to animals
88 86 not 87
89 limit 88 to yr="2000 -Current"

EMBASE (1974-present):
1 exp BRAIN INJURIES,TRAUMATIC/
2 "traumatic brain injur* ".ab,kw,ti.
3 (TBI* or mTBI*).ab,kw,ti.
4 "head trauma* ".ab,kw,ti.

5 "head injur* ".ab,kw,ti.
6 "brain trauma* ".ab,kw,ti.
7 "acquired brain injur* ".ab,kw,ti.
8 (brain and concussion*).ab,kw,ti.
9 (brain and concussive).ab,kw,ti.
10 (Head and concussion*).ab,kw,ti.
11 (head and concussive).ab,kw,ti.
12 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11
13 exp DEVELOPING COUNTRIES/
14 "developing countr* ".ab,kw,ti.
15 "developing world* ".ab,kw,ti.
16 "LMIC*".ab,kw,ti.
17 "low* income* ".ab,kw,ti.
18 "middle income".ab,kw,ti.
19 "resource poor".ab,kw,ti.
20 "resource limited".ab,kw,ti.
21 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20
22 12 and 21
23 (pediatric* or paediatric* or child or children or infant* or neonat* or newborn* or adolescen*).ab,kw,ti.
24 22 and 23
25 limit 22 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)") [Limit not valid in Embase; records were retained]
26 24 or 25
27 exp AFRICA/
28 Africa.ab,kw,ti.
29 (Algeria* or Angola* or Benin or Botswana* or Burkina or Burundi* or "Cabo Verde" or "Cape Verde" or Cameroon* or "Central African Republic" or Chad or Comoros or Congo* or "Cote d'Ivoire" or Djibouti or Egypt* or Guinea* or Eritrea* or Eswatini or Swaziland or Ethiopia* or Gabon or Gambia* or Ghana* or Kenya* or Lesotho or Liberia* or Libya* or Madagascar or Malawi* or Mali or Mauritania* or Mauritius or Morocc* or Mozambique or Namibia* or Niger or Nigeria* or Rwanda* or "Sao Tome and Principe" or Senegal* or Seychelles or "Sierra Leone" or Somalia or Sudan* or Tanzania* or Togo or Tunisia* or Uganda* or Zambia* or Zimbabwe* or Southafrica* or Maghreb*).ab,kw,ti.
30 (Sahara* or SubSahara*).ab,kw,ti.
31 27 or 28 or 29 or 30
32 12 and 31
33 23 and 32
34 limit 32 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)") [Limit not valid in Embase; records were retained]
35 33 or 34
36 exp ASIA/
37 exp FAR EAST/
38 exp ASIA, CENTRAL/
39 exp ASIA, SOUTH/
40 exp ASIA, SOUTHEASTERN/
41 exp ASIA, WESTERN/
42 exp MIDDLE EAST/
43 exp TRANSCAUCASIA/
44 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43
45 JAPAN/ or SINGAPORE/ or TAIWAN/ or REPUBLIC OF KOREA/ or BAHRAIN/ or ISRAEL/ or KUWAIT/ or QATAR/ or SAUDI ARABIA/ or UNITED ARAB EMIRATES/
46 44 not 45
47 (Afghan* or Armenia* or Azerbaijan* or Bangladesh* or Bhutan* or Cambodia* or China or Chinese or "North Korea*" or "People* Republic of Korea" or Georgia* or India or Indian or Indonesia* or Iran* or Iraq* or Jordan* or Kazakhstan* or Kyrgyz* or Laos or Lao or Leban* or Malay* or Maldives or Mongolia* or Myanmar or Burm* or Nepal* or Pakistan* or Philippines or "Sri Lanka*" or Syria* or Tajik* or Thailand or Thai or Turkey or Turkish or Turkmen* or Uzbek* or Vietnam* or Gaza or "West Bank" or Palestin* or Yemen*).ab,kw,ti.
48 46 or 47
49 12 and 48
50 23 and 49

51 limit 49 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)") [Limit not valid in Embase; records were retained]
52 50 or 51
53 exp LATIN AMERICA/
54 exp SOUTH AMERICA/
55 exp CENTRAL AMERICA/
56 exp CARIBBEAN REGION/
57 MEXICO/
58 53 or 54 or 55 or 56 or 57
59 (Argentin* or Belize or Bolivia* or Brazil* or Colombia* or Cuba* or Chile* or "Costa Rica*" or Dominica* or Ecuador* or Salvador* or Grenada* or Guatemala* or Guyana* or Haiti* or Hondura* or Jamaica* or Mexico or Mexican* or Nicaragua* or Paraguay* or Peru or Peruvian* or "St* Lucia*" or "St* Vincent" or Suriname or Uruguay* or Venezuela*).ab,kw,ti.
60 58 or 59
61 12 and 60
62 23 and 61
63 limit 61 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)") [Limit not valid in Embase; records were retained]
64 62 or 63
65 exp PACIFIC ISLANDS/
66 exp POLYNESIA/
67 exp MELANESIA/
68 exp MICRONESIA/
69 65 or 66 or 67 or 68
70 AUSTRALIA/ or SOUTH AUSTRALIA/ or WESTERN AUSTRALIA/ or NEW ZEALAND/ or HAWAII/ or NEW CALEDONIA/
71 69 not 70
72 (Samoa* or Fiji* or Kiribati* or "Marshall Island*" or Micronesia* or Nauru* or "Papua New" or Polynesia* or "Solomon Island*" or "Timor Leste" or Tonga* or Tuvalu* or Vanuatu*).ab,kw,ti.
73 71 or 72
74 12 and 73
75 23 and 74
76 limit 74 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)") [Limit not valid in Embase; records were retained]
77 75 or 76
78 exp RUSSIA/
79 ALBANIA/ or "BOSNIA AND HERZEGOVINA"/ or BELARUS/ or BULGARIA/ or KOSOVO/ or MOLDOVA/ or MONTENEGRO/ or "REPUBLIC OF NORTH MACEDONIA"/ or ROMANIA/ or SERBIA/ or UKRAINE/
80 (Russia* or Albania* or Bosnia* or Belarus* or Bulgaria* or Kosovo or Kosova* or Moldova* or Montenegr* or "North Macedonia*" or Romania* or Serbia* or Ukrain*).ab,kw,ti.
81 78 or 79 or 80
82 12 and 81
83 23 and 82
84 limit 82 to ("all infant (birth to 23 months)" or "all child (0 to 18 years)" or "adolescent (13 to 18 years)") [Limit not valid in Embase; records were retained]
85 83 or 84
86 22 or 32 or 49 or 61 or 74 or 82
87 (pediatric* or paediatric* or child* or children or infant* or neonat* or newborn* or adolescen*).ab,kw,ti.
88 86 and 87
89 limit 86 to (infant <to one year> or child <unspecified age> or preschool child <1 to 6 years> or school child <7 to 12 years> or adolescent <13 to 17 years>)
90 88 or 89
91 limit 90 to animal studies
92 90 not 91
93 limit 92 to yr="2000 -Current"
94 limit 93 to conference abstracts
95 93 not 94

Global Health:

1 TRAUMA/
2 BRAIN/
3 1 and 2
4 "traumatic brain injur* ".ab,id,ti.
5 (TBI* or mTBI*).ab,id,ti.
6 "head trauma* ".ab,id,ti.
7 "head injur* ".ab,id,ti.
8 "brain trauma* ".ab,id,ti.
9 "acquired brain injur* ".ab,id,ti.
10 (brain and concussion*).ab,id,ti.
11 (brain and concussive).ab,id,ti.
12 (head and concussion*).ab,id,ti.
13 (head and concussive).ab,id,ti.
14 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13
15 exp DEVELOPING COUNTRIES/
16 "developing countr* ".ab,id,ti.
17 "developing world* ".ab,id,ti.
18 "LMIC*".ab,id,ti.
19 "low* income* ".ab,id,ti.
20 "middle income".ab,id,ti.
21 "resource poor".ab,id,ti.
22 "resource limited".ab,id,ti.
23 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22
24 14 and 23
25 (pediatric* or paediatric* or child* or children or infant* or neonat* or newborn* or adolescen*).ab,id,ti.
26 24 and 25
27 CHILDREN/ or ADOLESCENTS/
28 24 and 27
29 26 or 28
30 exp AFRICA/
31 Africa.ab,id,ti.
32 (Algeria* or Angola* or Benin or Botswana* or Burkina or Burundi* or "Cabo Verde" or "Cape Verde" or Cameroon* or "Central African Republic" or Chad or Comoros or Congo* or "Cote d'Ivoire" or Djibouti or Egypt* or Guinea* or Eritrea* or Eswatini or Swaziland or Ethiopia* or Gabon or Gambia* or Ghana* or Kenya* or Lesotho or Liberia* or Libya* or Madagascar or Malawi* or Mali or Mauritania* or Mauritius or Morocc* or Mozambique or Namibia* or Niger or Nigeria* or Rwanda* or "Sao Tome and Principe" or Senegal* or Seychelles or "Sierra Leone" or Somalia or Sudan* or Tanzania* or Togo or Tunisia* or Uganda* or Zambia* or Zimbabwe* or Southafrica* or Maghreb*).ab,id,ti.
33 (Sahara* or SubSahara*).ab,id,ti.
34 30 or 31 or 32 or 33
35 14 and 34
36 25 and 35
37 27 and 35
38 36 or 37
39 exp ASIA/
40 exp EAST ASIA/
41 exp CENTRAL ASIA/
42 exp SOUTH ASIA/
43 exp SOUTHEAST ASIA/
44 exp WEST ASIA/
45 exp MIDDLE EAST/
46 39 or 40 or 41 or 42 or 43 or 44 or 45
47 JAPAN/ or SINGAPORE/ or TAIWAN/ or REPUBLIC OF KOREA/ or BAHRAIN/ or ISRAEL/
48 KUWAIT/ or QATAR/ or SAUDI ARABIA/ or UNITED ARAB EMIRATES/
49 47 or 48
50 46 not 49
51 (Afghan* or Armenia* or Azerbaijan* or Bangladesh* or Bhutan* or Cambodia* or China or Chinese or "North Korea*" or "People* Republic of Korea" or Georgia* or India or Indian or Indonesia* or Iran* or Iraq* or Jordan* or Kazakhstan* or Kyrgyz* or Laos or Lao or Leban* or Malay* or Maldives or Mongolia* or Myanmar or Burm* or Nepal* or Pakistan* or Philippines or "Sri Lanka*" or Syria* or Tajik* or Thailand or

Thai or Turkey or Turkish or Turkmen* or Uzbek* or Vietnam* or Gaza or "West Bank" or Palestin* or Yemen*).ab,id,ti.
52 50 or 51
53 14 and 52
54 25 and 53
55 27 and 53
56 54 or 55
57 exp LATIN AMERICA/
58 exp SOUTH AMERICA/
59 exp CENTRAL AMERICA/
60 exp CARIBBEAN/
61 MEXICO/
62 (Argentin* or Belize or Bolivia* or Brazil* or Colombia* or Cuba* or Chile* or "Costa Rica*" or Dominica* or Ecuador* or Salvador* or Grenada* or Guatemala* or Guyana* or Haiti* or Hondura* or Jamaica* or Mexico or Mexican* or Nicaragua* or Paraguay* or Peru or Peruvian* or "St* Lucia*" or "St* Vincent" or Suriname or Uruguay* or Venezuela*).ab,id,ti.
63 57 or 58 or 59 or 60 or 61 or 62
64 14 and 63
65 25 and 64
66 27 and 64
67 65 or 66
68 exp PACIFIC ISLANDS/
69 exp POLYNESIA/
70 exp MELANESIA/
71 exp MICRONESIA/
72 68 or 69 or 70 or 71
73 AUSTRALIA/ or SOUTH AUSTRALIA/ or WESTERN AUSTRALIA/ or NEW ZEALAND/ or HAWAII/ or NEW CALEDONIA/
74 72 not 73
75 (Samoa* or Fiji* or Kiribati* or "Marshall Island*" or Micronesia* or Nauru* or "Papua New" or Polynesia* or "Solomon Island*" or "Timor Leste" or Tonga* or Tuvalu*
or Vanuatu*).ab,id,ti.
76 74 or 75
77 14 and 76
78 25 and 77
79 27 and 77
80 78 or 79
81 exp RUSSIA/
82 ALBANIA/ or "BOSNIA AND HERZEGOVINA"/ or BELARUS/ or BULGARIA/ or KOSOVO/ or MOLDOVA/ or MONTENEGRO/ or "REPUBLIC OF NORTH MACEDONIA"/ or ROMANIA/ or SERBIA/ or UKRAINE/
83 (Russia* or Albania* or Bosnia* or Belarus* or Bulgaria* or Kosovo or Kosova* or Moldova* or Montenegr* or "North Macedonia*" or Romania* or Serbia* or Ukrain*).ab,id,ti.
84 81 or 82 or 83
85 14 and 84
86 25 and 85
87 27 and 85
88 86 or 87
89 29 or 38 or 56 or 67 or 80 or 88
90 limit 89 to yr="2000 -Current"

WHO Global Index Medicus:
Key word “traumatic brain injury” in All Regional Indexes using filters for paediatric population and year range 2000 – 2020

Appendix S3: Data Extraction Form

On Excel Sheet

Journal Pre-proof

Appendix S4: Characteristics of the 136 included studies and their included participants, ordered alphabetically by study design

Supplementary Table 1. Characteristics of the 136 included studies and their included participants, ordered alphabetically by study design. Studies that had a sample population of less than 50 individuals with paediatric traumatic brain injury are shaded in grey.

Author, Year (Study ID)	Country(s) being studied	Inclusion Criteria	Number of paediatric TBI patients	Age range of paediatric TBI patients included	Number of male paediatric TBI patients (% of all paediatric TBI patients)	Study period (years)
Before-and-after study						
Ha 2018	Vietnam	All individuals who had been in road traffic accidents in Cu Chi district as per hospital and health office records	9.7 per 100, 000 (before) to 1.3 per 100, 000 (after) [specific numbers not provided]	0 years to 14 years	Not provided	2005 - 2006, 2009-2010
Cross-sectional study						
Diaz-Olavarrieta 2011	Mexico	Children under 5, who suffered head trauma and were admitted to the National Paediatrics Institute in Mexico City	120	0 years to 5 years	79 (66)	2005
Fatigba 2011	Benin	Patients admitted from January 1, 2008 to June 30, 2009 in Borgou Departmental Hospital, Benin for traumatic brain injuries after road crash	37	0 years to 10 years	Not provided	2008 -2009
Gu 2010	China	Patients with traumatic brain injury who survived the massive earthquake (magnitude 8) in Wenchuan, Sichuan Province, on 12 May 2008	11	0 years to 10 years	Not provided	2008
Hafiz 2011	Malaysia	Children aged 3 years old and below who were admitted to the Kuala Lumpur Hospital with diagnosis of moderate to severe traumatic brain injury from period of June 2007 to September 2009	153	0 years to 3 years	Not provided	2007 - 2009

Journal Pre-proof

Jiang 2013	China	Paediatric victims who were admitted to West China Hospital, Sichuan University following the Lushan earthquake in 2013 and Wenchuan earthquake in 2008	13	0 years to 14 years	Not provided	2008 and 2013
Mahdian 2015	Iran	Traffic accident victims hospitalized more than 24 Hours in a Level III Trauma Center, Kashan County, Iran, during 2012-2013	103	0 years to 15 years	81 (79)	2012 - 2013
Melo 2004	Brazil	Victims with head injury assisted at the General Hospital of Bahia during 2001	76	0 years to 10 years	45 (59)	2001
Melo 2006	Brazil	All TBI victims, aged until 19 years admitted in a reference trauma center	213	0 years to 9 years	Not provided	2003 - 2004
Ortiz-Prado 2020	Ecuador	All hospital admissions and deaths due to traumatic brain injury registered in Ecuador from 2004 to 2016	38971	0 years to 14 years	23987 (62)	2004 - 2016
Zhang 2014	China	Inpatients at 140 hospitals who injured in the Lushan earthquake on April 20, 2013	6	0 years to 10 years	Not provided	2013
Prospective cohort						
Abdelaziz 2014	Egypt	Patients admitted to Alexandria Main University Hospital with head injuries after road traffic accidents during the Egyptian revolution period between January 2011 and July 2011.	55	6 months to 10 years	Not provided	2011
Adegoke 2011	Nigeria	All patients with injury who were admitted to the Children's Emergency Room at the Wesley Guild Hospital, Ilesa, Osun State, Nigeria, over a period of 2 years (1	183	≤ 16 years (not defined)	Not provided	2007 - 2009

Journal Pre-proof

Journal Pre-proof

		June 2007 - 30 May 2009)				
Adeleye 2009	Nigeria	All head injury patients who presented to the neurosurgical unit at the University of Ibadan and University College Hospital, Ibadan, Nigeria between March and December 2005	30	6 months to 15 years	Not provided	2005
Aenderl 2014	Ethiopia	All head injury patients who presented to Jimma University Specialized Hospital between March and June 2010	17	3 years to 15 years	Not provided	2010
Arango 2008	Colombia	Children aged between 1 and 5 years, treated for TBI between June, 2003 and November, 2004, who were residents of the Aburra valley in north-western Colombia, and did not suffer from other neurological problems	90	1 year to 5 years	58 (64)	2003 - 2004
Atwa 2017	Egypt	Patients, aged 18 years or less, who presented to the emergency department in the Suez Canal University Hospital, with head injuries, in the period from March 2014 to February 2015	70	3 months to 16 years	41 (59)	2014 - 2015
Bedry 2020	Ethiopia	Paediatric TBI cases, aged between 2 months and 14 years and that visited HUCSH from September 2017 to September 2018.	317	2 months to 14 years	218 (69)	2017 - 2018
Chaitanya 2018	India	All children < 16 years with TBI reporting to the neurosurgical emergency department at Aditya Birla Memorial Hospital	76	0 to 16 years	51 (67)	2015 - 2017
Cheng 2017	China	All individuals who had	7.17 per 100, 000	0 years to 14 years	Not provided	2006 - 2013

		traumatic brain injury listed as a cause of death in China, between 1 January 2006 and 31 December 2013	[specific numbers not provided]			
Dirim 2005	Turkey	Severe head trauma patients admitted and hospitalised in Izmir Atatürk Training and Research Hospital	2	5 years to 12 years	Not provided	2003 - 2004
Djientcheu 2016	Cameroon	All the patients admitted for head injury in the emergency units of the selected hospitals in Cameroon.	232	0 years to 10 years	Not provided	2010 - 2011
Emejulu 2010	Nigeria	All patients with acute EDH managed in Nnamdi Azikiwe University Teaching Hospital from May 2006 to July 2013.	52	9 months to 15 years	13 (48)	2006 - 2007
Emejulu 2014	Nigeria	Patient with acute extradural hematoma who were managed in a Nigerian neurosurgical center from May 2006 to July 2013	6	0 years to 10 years	Not provided	2006 - 2013
Hassan 2017	Pakistan	Traumatic brain injury patients presenting to a teaching hospital of khyber pakhtunkhwa (Department of Neurosurgery, Lady Reading Hospital, Peshawar) from 1st September 2013 to 31st August 2014	264	0 years to 10 years	Not provided	2013 - 2014
Idowu 2014	Nigeria	Patients with traumatic brain (TBI) and spine injury (TSI) who presented at Lagos State University Teaching Hospital	203	0 years to 9 years	Not provided	2012 - 2013
Karmacharya 2015	Nepal	All children who presented with head injuries to the Neurosurgery Unit of Manipal teaching Hospital in Pokhara	287	0 years to 15 years	196 (68)	2014
Khan 2019	India	Patients presenting with TBI	211	0 years to 14 years	162 (77)	2016 - 2017

		to a level I trauma center in India				
Kihiko 2010	Kenya	Children aged 1-13 years who sustained injuries after failing from any height, and were admitted to Kenyatta National Hospital, Nairobi, from November 2006 to February 2007	32	1 year to 13 years	Not provided	2006 - 2007
Kool 2012	Fiji	All fatal and hospitalised head injury patients recorded in the Fiji Injury Surveillance in Hospital system	75	0 years to 14 years	Not provided	2005 - 2006
Kuo 2017	Uganda	TBI patients presenting to Mulago National Referral Hospital (MNRH), Kampala, Uganda	93	1 year to 16 years	67 (72)	2016
Lafta 2019	Iraq	Paediatric age group from 1 year to 14 years old with surgically operated head trauma, in the period from 1/10/2014 till 1/10/2015 in a neurosurgery hospital in Baghdad	52	1 year to 14 years	28 (54)	2014 - 2015
Landes 2017	Ethiopia	All head injured patients presenting to the Emergency Centre of Tikur Anbessa Specialised Hospital, Addis Ababa	9	0 years to 16 years	Not provided	2012
Li 2018	China	1656 Chinese children recruited between fall 2004 and spring 2005 from Jintan city	99	6 years to 12 years	52 (53)	2004 - 2013
Liao 2012	China	A random selection of 8291 TBI patients, 17 years or younger, diagnosed with TBI in 2005 to 2008 in Taiwan	6521	0 years to 14 years	Not provided	2005 - 2008
Liu 2013	China	1656 Chinese children	167	6 years to 6 years	96 (57)	2004 - 2005

Journal Pre-proof

		recruited between fall 2004 and spring 2005 from Jintan city				
Mabiala-Babela 2010	Brazil	Infants aged 1–24 months admitted to the emergency department of the university hospital of Brazzaville (Congo) from 1st January 2007 to December 31, 2008	213	0 years to 9 years	Not provided	2003
Maia 2014	Brazil	Patients who suffered traumatic brain injuries (TBI) in the period from July 31, 2007 to August 1, 2008, and were seen at selected trauma units in Salvador, Bahia, Brazil	422	0 years to 15 years	Not provided	2007 - 2008
Masaeli 2019	Iran	Head trauma children who were referred to the emergency departments of Firouzgar and Besat Hospitals, Tehran, Iran, from September 2018 to May 2019	368	0 years to 6 years	Not provided	2018 - 2019
Mc Fie 2016	South Africa	South African youth rugby union players who played at the 2011 to 2014 South African Rugby Union Youth Week Tournaments.	108	0 years to 16 years	108 (100)	2011 -2014
Munakomi 2016	Nepal	Neurosurgical trauma patients who presented with mild-to-severe traumatic brain injury (TBI) from January 2013 to April 2014 at a tertiary care center in rural Nepal.	123	0 years to 10 years	Not provided	2013 - 2014
Myers 2017	Kenya	Every sixth patient registered in triage during 8 hour shifts from 11 March 2015 to 30 May 2015 at the Accident and Emergency	2	0 years to 5 years	2 (100)	2015

		Department of Kenyatta National Hospital, Nairobi, Kenya				
Nnadi 2014	Nigeria	Children managed for head injuries in a center in Nigeria from July 2010 to December 2013	46	0 years to 10 years	Not provided	2010 - 2013
Nordon 2012	Brazil	Children who were admitted in the emergency service of Unidade Regional de Emergencia – Conjunto Hospitalar de Sorocaba due to traumatic brain injury	68	0 years to 16 years	Not provided	2010
Odebode 2005	Nigeria	Head-injured patients managed at the University of Ilorin Teaching Hospital, Ilorin, Nigeria between January 2001 and June 2003	10	9 months to 15 years	Not provided	2001 - 2013
Ohaegbulam 2011	Nigeria	Head injury patients who presented for CT scan between January 2009 and April 2010 at Memfys Hospital for Neurosurgery (MHN), Enugu, Nigeria	12	0 years to 10 years	17 (59)	2009 - 2010
Oluwole 2011	Nigeria	Patients who presented in the Accident & Emergency Unit of a Teaching Hospital in Ibadan, Nigeria, a tertiary Health Care Facility, and evidence of traumatic brain injury: impairment or loss of consciousness, confusion, focal neurological deficits like hemiparesis and cranial nerve palsies, presence of depressed skull fracture, or brain CT evidence of contusion, parenchymal and extra-axial	44	0 years to 12 years	6 (60)	> 2000 (Not defined)

		haemorrhages				
Punchak 2018	Uganda	Traumatic Brain Injury patients who were <18 years and treated at Mbarara Regional Referral Hospital between November 2016 and June 2017	10	0 years to 2 years	Not provided	2016 - 2017
Qureshi 2013	Malawi	All patients that presented to the casualty department at Kamuzu Central Hospital (KCH) in Lilongwe Malawi secondary to head injury	20	0 years to 15 years	Not provided	2011
Rabiu 2017	Nigeria	Patients with TBI that were managed in a Rural Nigerian Neurosurgical Centre	20	0 years to 16 years	Not provided	2010 - 2012
Ramos-Usuga 2019	Mexico	Children with traumatic brain injury in Guadalajara, Mexico	46	7 years to 15 years	31 (67)	> 2000 (Not defined)
Simon 2013	Tanzania	Paediatric injury patients admitted to Bugando Medical Centre from August 2011 to April 2012	29	1 month to 10 years	Not provided	2011 - 2012
Slaveykov 2019	Bulgaria	Children with head injury who presented to the University Hospital "Prof. Dr. Stoian Kirkovich", Stara Zagora, Bulgaria, Department of Neurosurgery.	64	0 years to 15 years	Not provided	2016 - 2018
Solagberu 2014	Nigeria	Injured child pedestrians (≤15 years) who presented from 12 December 2011 to 11 December 2013 at the Surgical Emergency Room (SER) of the Lagos State University Teaching Hospital (LASUTH), Ikeja, Nigeria	108	0 years to 15 years	60 (56)	2011 - 2013
Tabish 2006	India	All children below the age of 15 with TBI who were admitted to the Accident &	1500	0 years to 15 years	903 (60)	2003

Journal Pre-proof

		Emergency Department of Sher-e-Kashmir Institute of Medical Sciences, Srinagar (India)				
Thapa 2010	India	Patients with traumatic brain injury (TBI) (July 2007-2008) admitted after 24h of injury at All India Institute of Medical Sciences (AIIMS), Ansari Nagar, New Delhi 110029, India.	93	0 years to 10 years	Not provided	2007 - 2008
Umerani 2014	Pakistan	Patients presenting with head injury to the Accident and Emergency Department of a tertiary care centre in Pakistan	62	0 years to 10 years	41 (66)	2009 - 2011
Wani 2017	India	Patients with TBI, 18 years or less in age, managed in an Indian Department of Neurosurgery	294	0 years to 12 years	Not provided	2011 - 2013
Xing 2008	China	Traumatic brain injury patient in 77 hospitals in eastern China, 2004	1022	0 years to 14 years	Not provided	2004
Retrospective cohort						
Abdelgadir 2018	Uganda	All paediatric neurosurgical cases between 2012 and 2015 who were admitted at Mbarara Regional Referral Hospital (MRRH) in western Uganda.	257	2 months to 11 years	Not provided	2012 - 2015
Adam 2016	Ghana	All patients admitted into the Tamale Teaching Hospital, Ghana and diagnosed as having TBI	189	≤ 16 years (not defined)	68 (72)	2009 - 2012
Agrawal 2008	Nepal	All children (age <16 years) with head injury from April 2005 to March 2006 in Eastern Nepal	43	6 months to 16 years	26 (60)	2005 - 2006
Agrawal 2011	India	All consecutive patients who were admitted from January	20	0 years to 10 years	11 (55)	2007 - 2009

		2007 to December 2009 in the critical care unit of the Datta Meghe Institute of Medical Sciences, Sawangi (Meghe), Wardha, India for the management of traumatic brain injury				
Aras 2017	Turkey	Patients with head injury who were admitted to the Trauma and Emergency Surgery Department of Istanbul University, Istanbul School of Medicine, Istanbul, Turkey from January 1, 2014, through 31 December, 2014	323	0 years 10 15 years	Not provided	2014
Bashir 2013	Pakistan	Craniocerebral injuries of unarmoured civilians secondary to suicidal and implanted bombs as encountered at the Aga Khan University Hospital, Pakistan	4	5 years to 14 years	3 (75)	> 2000 (Not defined)
Boniface 2017	Tanzania	Traumatic brain injury patients who attended Muhimbili Orthopedic Institute between January 2014 and June 2014	169	1 year to 15 years	Not provided	2014
Buitendag 2017	South Africa	All patients aged ≤18 years old who were admitted by the Pietermaritzburg Metropolitan Trauma Service (PMTS) with TBI between December 2012 and December 2016	563	≤ 16 years (not defined)	398 (71)	2012 - 2016
Cavalcanti 2009	Brazil	0-4-year-old children who died and had autopsies performed at the Department of Forensic Medicine of the city of Campina Grande, PB, Brazil, between January 2003	27	0 years to 4 years	Not provided	2003 - 2007

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		and December 2007				
Cavalcanti 2014	Brazil	Child and adolescent victims of automobile accidents who died and had their forensic medical report kept in the Legal Medical Institute of Campina Grande, Brazil, between January 2008 and December 2011	83	0 year to 14 years	59 (71)	2008 -2011
Chong 2017	China, Pakistan, Vietnam, India, Malaysia	Children <16 years old who presented within 24 hours of head injury and were admitted for observation or required a computed tomography of the brain from the emergency department at eight PATOS centres	438	0 years to 16 years	Not provided	2014 - 2015
De Almeida 2016	Brazil	All TBI cases in Brazil between 2008 and 2012 as collected through the website of the Information Technology Department of the Unified Health System (DATASUS) maintained by the Brazilian Ministry of Health	19180	0 years to 14 years	Not provided	2008 - 2012
Edwards 2014	Afghanistan and Iraq	Children with blast injury in Afghanistan and Iraq from 2002 to 2010 treated at US military treatment facilities	909	0 years to 14 years	Not provided	2005 - 2010
Egbohou 2019	Togo	0 to 15 years old admitted during the period from 1 January 2012 to 30 June 2018 at the ICU of SOUH of Lome	91	0 years to 15 years	61 (67)	2012 - 2018
Eloqayli 2010	Jordan	All childhood cases of traumatic acute Epidural Haematoma (EDH) admitted to King Abdullah University Hospital (KAUH), Jordan	22	0 years to 16 years	12 (55)	2005 - 2006

		between 2005-2006				
Er 2017	Turkey	Patients who were injured in the Syrian Civil War and transferred to the emergency department at Antakya State Hospital between July 2013 and October 2014	156	≤ 16 years (not defined)	Not provided	2013 - 2014
Eshete 2018	Ethiopia	Patients with head injury admitted to surgical ward from December 2014 to November 2016 at Dilla University Referral Hospital	31	0 years to 15 years	Not provided	2014 - 2016
Esin 2013	Nigeria	Children who were admitted for various injuries in the female/paediatric surgical ward of Federal Medical Centre, Gombe, Nigeria from January 2007 to December 2009.	Unspecified	2 months to 15 years	Not provided	2007 - 2009
Fakharian 2014	Iran	Patients under the age of two who were hospitalized for more than 24 hours between January 2004 and January 2010 in Iran	604	0 years to 2 years	343 (57)	2004 - 2010
Faried 2017	Indonesia	Moderate and severe TBI resulting from motorcycle crashes from January 1, 2013 to June 30, 2014 in Bandung, Indonesia.	4	0 years to 5 years	Not provided	2013 - 2014
Guillen-Pinto 2013	Peru	Traumatic brain injury (TEC) in children seen at the Cayetano Heredia National Hospital from 2004 to 2011	352	0 years to 14 years	202 (64)	2004 - 2011
Guloglu 2012	Turkey	Paediatric patients who were admitted to Istanbul University, Istanbul Medical Faculty, Emergency Surgery Department	6	0 years to 9 years	Not provided	2001 - 2010

Gupta 2017	Nepal	Patients aged less than 16 years with history of trauma from January 1st 2013 to 31st December 2013 who attended the Emergency Department in a Tertiary Care Center in Eastern Nepal	190	5 years to 10 years	Not provided	2013
Guzel 2006	Turkey	Trauma cases admitted to the Paediatric Emergency Unit of Trakya University Medical Faculty between January 2003 and August 2005	42	1 year to 14 years	33 (79)	2003 - 2005
Guzel 2007	Turkey	Patients who presented to the paediatric emergency unit in the Department of Child Health and Diseases Department, Edirne, Turkey with the complaint of falling	136	5 months to 13 years	Not provided	2003 - 2005
Hassen 2012	Tunisia	Children hospitalized for traumatic brain injury in the Hospital of Child of Tunis during a 1-year period (2007)	298	1 month to 15 years	Not provided	2007
Hode 2016	Benin	All children from 0 to 16 years victims of cranial trauma admitted from July 2012 to December 2013 at National University Hospital Center in Cotonou (CNHU-HKM)	102	0 years to 15 years	Not provided	2012 - 2013
Hoz 2019	Iraq	Paediatric patients who sustained head injuries due to metallic ceiling fans admitted to the Emergency Department of Neurosurgery Teaching Hospital in Baghdad, Iraq, during January 2015 to January 2017	29	0 years to 9 years	12 (41)	2015 - 2017
Ibrahim 2015	Nigeria	Non-accidental TBI in children starting from	109	0 years to 16 years	67 (61)	2008 - 2014

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		September 2008 to March, 2014 at Murtala Mohammad Specialist Hospital				
Iranmanesh 2009	Iran	Patients younger than 18-years-old admitted to the surgery ward of Ali-E-Bne-Abitaleb Hospital, Rafsanjan due to head trauma	247	0 years to 11 years	Not provided	2003- 2005
Isik 2011	Turkey	Patients younger than 14 years old with head injury, treated in the Neurosurgery Department of Samsun Mehmet Aydın Education and Research Hospital between January 2003 and June 2008	851	0 years to 14 years	550 (65)	2003 - 2008
Jagnoor 2012	India	Patients presenting with fall related injury at the Emergency Department of the Nehru Hospital, Chandigarh, India between March 2008 and February 2009	408	0 years to 14 years	Not provided	2008 - 2009
Jasper 2014	Nigeria	Patients that presented with head injury at the Accident and Emergency unit of the Jos University Teaching Hospital (JUTH), Jos, Nigeria with traumatic brain injury from February 2012 to January 2013	56	1 years to 10 years	Not provided	2012 - 2013
Jha 2011	Nepal	Head injuries in road traffic accident victims, who were autopsied at the B.P. Koirala Institute of Health Sciences, Dharan, Nepal from Feb 2006 to May 2007	3	0 years to 10 years	3 (100)	2006 - 2007
Ji 2016	China	Children with head-injuries across China as per the National Injury Surveillance	42663	0 years to 14 years	Not provided	2014

		System of China, 2014				
Jianbo 2012	China	Hospitalized TBI patients (0–17 years of age) treated at the Wuhan Medical Care Center for Women and Children in China between 2002-2011.	4230	0 years to 15 years	2749 (65)	2002 - 2011
Kiboi 2010	Kenya	Patients who were diagnosed with traumatic ASDH between January 2000 and December 2009 at Kenyatta National Hospital	10	0 years to 13 years	Not provided	2000 -2009
Kiboi 2011	Kenya	Patients presenting at the Kenyatta National Hospital between January 2000 and December 2009 with traumatic intracranial hematomas.	34	0 years to 13 years	Not provided	2000 - 2009
Kiboi 2015	Kenya	Patients who were admitted to the neurosurgical unit at the Kenyatta National Hospital and diagnosed with extradural hematoma between January 2007 and December 2011	13	0 years to 13 years	Not provided	2007 - 2011
Klimo 2015	Iraq and Afghanistan	Children (<18 years old) in the Joint Theater Trauma Registry with isolated head injury (defined as an Abbreviated Injury Score Severity Code >3) and treated at a US combat support hospital in Iraq or Afghanistan (2004-2012)	354	0 years to 12 years	Not provided	2004 - 2012
Kucuk 2017	Turkey	Children exposed to head trauma due to an accident caused by a falling television and treated in the neurosurgery department of the Erciyes University School	36	15 months to 11 years	18 (50)	2007 - 2014

		of Medicine				
Li 2012	China	Deaths from blunt head injury	22	0 years to 8 years	9 (41)	2009 - 2011
Li 2015	China	Civilian inpatients of Chinese military hospitals diagnosed with TBI between 2001-2007	14178	0 years to 10 years	9416 (66)	2001 - 2007
Li 2017	China	Children with TBI aged 0-17 years between 2001 and 2007 as retrieved from the Chinese Trauma Database	18922	0 years to 14 years	12791 (68)	2001 - 2007
Loredo-Abdala 2018	Mexico	All cases of paediatric abusive head trauma (defined as skull fracture or intracranial haemorrhage in a child under the age of 5 years with a suspicious mechanism or evidence of other intentional injuries, such as retinal haemorrhages, old or new fractures, or soft tissue bruising) involving patients who presented to Le Bonheur Children's Hospital (LBCH) from 2009 through 2014 were identified.	14	2 months to 14 months	Not provided	2001 - 2010
Loredo-Abdalá 2020	Mexico	Children suspect with abusive head trauma in emergency rooms in three Mexican hospitals	21	1 month to 24 months	Not provided	2012 - 2015
Lynch 2013	Tanzania	TBI patients who present to Kilimanjaro Christian Medical Center Casualty Department in Moshi, Tanzania.	24	0 years to 14 years	32 (62)	2013
Martin 2010	Iraq	Paediatric neurosurgical patients at a field hospital in Iraq in 2007	26	0 years to 8 years	Not provided	2007
Masoumi 2017	Iran	Children with head trauma injuries referred to the emergency department of	44	0 years to 2 years	Not provided	2006 - 2007

		Imam Hossein Hospital between 2006 and 2007				
Mukhida 2006	Nepal	Patients <or=18 years who presented to Tribhuvan University Teaching Hospital between April 1, 2001 and April 1, 2004 with acute neurological trauma and were subsequently admitted to hospital	235	0 years to 11 years	Not provided	2001 - 2004
Naidoo 2015	South Africa	Paediatric trauma patients (younger than 16) admitted to a level 1 trauma intensive care unit (TICU) at Inkosi Albert Luthuli Central Hospital, Durban, South Africa	112	0 years to 16 years	Not provided	2008 - 2012
Omerhodzic 2020	Bosnia and Herzegovina	Patients presenting with head injury to the Department of Neurosurgery of University Clinical Centre Sarajevo during the period 1 July 2006 – 30 June 2012	254	0 years to 10 years	Not provided	2006 - 2012
Osifo 2010	Nigeria	Patients with falls from heights, who presented between June 2007 and May 2008 at the Accident and Emergency Center of the University of Benin Teaching Hospital	22	0 years to 10 years	10 (45)	2007 - 2008
Parrado 2017	Colombia	Patients that had consulted at the Fundacion Valle del Lili pediatric Emergency Room between January of 2011 and December of 2015 because of TBI due to gunshot-wounds	18	0 years to 10 years	Not provided	2011 - 2015
Peymani 2012	Iran	Fatal pedestrian accidents in Fars Province of Iran	140	0 years to 15 years	Not provided	2009 - 2011
Podolsky-	Brazil	Children with a traumatic	26	3 months to 10	Not provided	2013 - 2016

Gondim 2018		brain injury admitted to University Hospital, Ribeirão Preto Medical School, between January 2013 and December 2016, submitted to any neurosurgical procedures		years		
Prasad 2015	India	Young children undergoing decompressive craniectomy (DC) for traumatic brain injury (TBI) at Jai Prakash Narayan Apex Trauma Centre, AlIMS,	71	0 years to 3 years	43 (61)	2008 - 2014
Prasad 2015	India	Pediatric patients (≤18 years) admitted with a diagnosis of traumatic posterior fossa extradural hematomas from January 2008 to February 2014	7	0 years to 10 years	Not provided	2008 - 2014
Saatian 2018	Iran	Patients with TBI during 2013 to 2016 in a single center in Hamedan, central Iran	2186	0 years to 10 years	1309 (60)	2013 - 2016
Satapathy 2016	India	Children <15 years with TBI at Department of Neurosurgery, S.C.B. Medical College, Cuttack, Odisha, India	147	0 years to 15 years	101 (69)	2012 - 2013
Singh 2014	India	Patients who presented to Christian Medical College, Ludhiana, between January 2005 and January 2010 with trauma as a result of kite flying	41	0 years to 16 years	Not provided	2005 -2010
Sundet 2018	Malawi	All children aged ≤16 who were treated in the casualty department at the central hospital in Lilongwe, Malawi, between 1 January 2009 and 31 December 2015	2155	0 years to 16 years	Not provided	2009 - 2015

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Suresh 2010	India	Children admitted with head injury due to TV fall in Kanchi Kamakoti CHILDS Trust Hospital, Nageswara Road, Nungambakkam, Chennai, Tamil Nadu during March 2007-February 2008	132	0 years to 16 years	Not provided	2007 - 2008
Tay 2016	Malaysia	All traumatic brain injury cases for children ages 0–19 included in the 2010 Malaysian National Trauma Database report	208	0 years to 14 years	Not provided	2010
Tokdemir 2009	Turkey	All cases patients to the emergency department of Firat University with suspected injury after involvement in a motor vehicle-related accident between January 2000 and January 2005.	211	0 years to 16 years	Not provided	2000 - 2005
Tran 2015	Uganda	Patients of all ages with a Glasgow Coma Scale (GCS) score of 8 or less (measured upon admission) at Mulago National Referral Hospital (Kampala, Uganda)	33	0 years to 14 years	Not provided	2008 - 2009
Tunthanathip 2017	Thailand	Children, who were younger than 15 years old with TBI and presented to the Division of Neurosurgery, Department of Surgery, Faculty of Medicine, Songklanagarind Hospital, Prince of Songkla University, Songkhla, Thailand	948	1 month to 14 years	603 (64)	2004 - 2015
Uche 2013	Nigeria	Neonatal patients with head injury from two tertiary hospitals in South-East Nigeria between July 2009	37	0 days to 28 days	Not provided	2009 - 2012

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		and June 2012				
Udoh 2013	Nigeria	All paediatric patients with traumatic brain injury who presented to the University of Benin Teaching Hospital between October 2006 and September 2011	122	0 years to 16 years	61 (50)	2006 - 2011
Vaghani 2013	India	Infants with traumatic brain injury admitted at JPNATC, AIIMS	29	1 month to 12 months	16 (67)	2009 - 2012
Wang 2018	China	Patients who were children and adolescent who had traumatic skull fractures admitted to our university affiliated hospitals between January 2003 and December 2010.	316	0 years to 15 years	220 (70)	2003 - 2010
Waqas 2017	Pakistan	Children less than 3 years of age admitted to Aga Khan University Hospital with a head injury	109	0 years to 3 years	75 (69)	2009 -2012
Waqas 2018	Pakistan	Children with TV trolley tip-over head injuries from January 2009 to April 2016 admitted to Aga Khan University Hospital, Karachi, Pakistan.	22	0 years to 3 years	Not provided	2009 - 2016
Xia 2012	China	Children less than 5 years of age admitted to WMCCWC with a discharge diagnosis of traumatic brain injury from January 1, 2002 to December 31, 2011	3061	0 years to 5 years	1966 (64)	2002 - 2011
Yagmur 2016	Turkey	Preschool children deaths from TBI (from records of the Morgue Department of the Council of Forensic Medicine in Istanbul)	203	0 months to 60 months	117 (58)	2008 - 2012

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Younis 2011	Palestine	Patients who were diagnosed with TBI and admitted to Rafidia, Al-Ittihad and the specialized Arab hospitals, Palestine in 2006 and 2007	95	0 years to 9 years	Not provided	2006 - 2007
Zhang 2019	China	Patients aged ≤17 years admitted to level 1 children's hospital located in Eastern China due to TBI between 1 January 2013 and 31 December 2015	830	0 years to 6 years	Not provided	2013 - 2015

Appendix S5: Total number of paediatric patients with TBI by severity

Supplementary Table 2. Paediatric patients with mild, moderate, or severe traumatic brain injury (TBI) as categorised by the Glasgow Coma Scale (GCS) in 40 studies with available data of the 136 included studies. Studies that are at a high risk of bias are shaded in grey.

Author, Year (Study ID)	**Country(s) being studied**	**Total number of paediatric patients with TBI by severity**			**Total number of paediatric patients with TBI**
		Mild	**Moderate**	**Severe**	
Abdelaziz 2014	Egypt	43	10	2	55
Abdelgadir 2018	Uganda	160	37	60	257
Agrawal 2008	Nepal	28	12	3	43
Atwa 2017	Egypt	57	9	4	70
Bashir 2013	Pakistan	2	1	1	4
Bedry 2020	Ethiopia	231	61	25	317
Buitendag 2017	South Africa	454	67	42	563

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Chaitanya 2018	India	46	11	19	76
Diaz-Olavarrieta 2011	Mexico	73	15	12	120
Dirim 2005	Turkey	2			2
Egbohou 2019	Togo			91	91
Eloqayli 2010	Jordan	8	8	6	22
Emejulu 2010	Nigeria	31	7	14	52
Eshete 2018	Ethiopia	14	8	9	31
Guillen-Pinto 2013	Peru			16	352
Hassen 2012	Tunisia	276	6	16	298
Hode 2016	Benin	55	35	12	102
Hoz 2019	Iraq	28		1	29
Isik 2011	Turkey	630	187	34	851
Karmacharya 2015	Nepal	218	60	9	287
Khan 2019	India	155	28	28	211
Kihiko 2010	Kenya	25	5	2	32
Kucuk 2017	Turkey	29	2	5	36
Kuo 2017	Uganda	46	31	16	93
Lafta 2019	Iraq	31	13	8	52
Li 2018	China	99			99

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Munakomi 2016	Nepal	110	8	5	123
Nordon 2012	Brazil	18	1	2	68
Odebode 2005	Nigeria	8	2		10
Omerhodzic 2020	Bosnia and Herzegovina	213	26	15	254
Prasad 2015	India	9	26	36	71
Ramos-Usuga 2019	Mexico	10	21	15	46
Satapathy 2016	India	83	43	21	147
Simon 2013	Tanzania	6	15	8	29
Solagberu 2014	Nigeria	40	33	35	108
Sundet 2018	Malawi	2086	17	52	2155
Tunthanathip 2017	Thailand	800	71	77	948
Udoh 2013	Nigeria	35	36	51	122
Vaghani 2013	India	18	4	7	29
Waqas 2018	Pakistan			1	22
	Totals (%)	6177 (75)	916 (11)	760 (9)	8277 (100)

Appendix S6: Mortality post paediatric traumatic post-injury

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Supplementary Table 3. Paediatric traumatic brain injury (TBI) mortality reported in 52 studies of the 136 included studies. Studies that are at a high risk of bias are shaded in grey.

Author, Year (Study ID)	Country(s) being studied	Total number of paediatric TBI patients within study population	Total number of paediatric patients that died from the TBI	Total number of paediatric patients that died from secondary consequences of TBI	All-cause paediatric TBI mortality	Case Fatality Ratio (CFR)
Abdelgadir 2018	Uganda	257			26	10.1167315
Adegoke 2011	Nigeria	183			14	7.65027322
Aenderl 2014	Ethiopia	17			0	0
Agrawal 2008	Nepal	43	3		3	6.97674419
Arango 2008	Colombia	90	3		3	3.33333333
Bedry 2020	Ethiopia	317			10	3.15457413
Boniface 2017	Tanzania	169			5	2.95857988
Buitendag 2017	South Africa	563	9		9	1.59857904
Chaitanya 2018	India	76			4	5.2631579
Chong 2017	Pakistan	101			48	47.5247525

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De Almeida 2016	Brazil	19,180			395	2.05943691
Diaz-Olavarrieta 2011	Mexico	120			6	5
Egbohou 2019	Togo	91	19	10	29	31.8681319
Eloqayli 2010	Jordan	22			3	13.6363636
Emejulu 2010	Nigeria	52			8	15.3846154
Fakharian 2014	Iran	604			5	0.82781457
Fekih 2012	Tunisia	298	6		6	2.01342282
Florou 2016	Romania	22	22		22	100
Guillen-Pinto 2013	Peru	352			16	4.54545455
Hode 2016	Benin	102	11		11	10.7843137
Hoz 2019	Iraq	29	1		1	3.44827586
Ibrahim 2015	Nigeria	109	6		6	5.50458716
Iranmanesh 2009	Iran	247	16		16	6.47773279
Isik 2011	Turkey	851	33		33	3.87779083
Jha 2011	Nepal	3			3	100
Karmacharya 2015	Nepal	287		4	8	2.78745645
Khan 2019	India	211			13	6.16113744
Kiboi 2010	Kenya	10			2	20
Kiboi 2015	Kenya	13			1	7.69230769

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Kool 2012	Fiji	75			6	8
Kucuk 2017	Turkey	36	3		3	8.33333333
Kuo 2017	Uganda	93	4		4	4.30107527
Lafta 2019	Iraq	52	5		5	9.61538462
Li 2012	China	22			22	100
Li 2015	China	14178			296	2.08774157
Li 2017	China	18922			381	2.01352923
Munakomi 2016	Nepal	123			4	3.25203252
Naidoo 2015	South Africa	112	18		23	20.5357143
Omerhodzic 2020	Bosnia and Herzegovina	254			6	2.36220472
Parrado 2017	Colombia	18			14	77.7777778
Peymani 2012	Iran	140	114	26	140	100
Prasad 2015	India	71		18	31	43.6619718
Qureshi 2013	Malawi	20			2	10
Saatian 2018	Iran	2186			30	1.37236963
Satapathy 2016	India	147		7	11	7.4829932
Tran 2015	Uganda	33			10	30.3030303
Tunthanathip 2017	Thailand	948			30	3.16455696

Vaghani 2013	India	29			3	10.3448276
Waqas 2018	Pakistan	22			1	4.54545455
Xia 2012	China	3061			8	0.2613525
Yagmur 2016	Turkey	203	203		203	100
Zhang 2019	China	830			5	0.60240964
	Totals (%)	65994 (100)	476 (1)	65 (0.1)	1944 (3)	2.94572234

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pTBI: paediatric traumatic brain injury
LMICs: low-and-middle-income countries
TBI: traumatic brain injury
HICs: high-income countries
WHO: World Health Organization
IQR: interquartile ranges
CFR: case fatality rate
GCS: Glasgow Coma Scale
GOS: Glasgow Outcome Scale

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Conflict of Interest

GCR is financially supported by the National Institute of Health Research (NIHR) School for Primary Care Research (SPCR), the Naji Foundation, and the Rotary Foundation. All other authors declare no competing interests.

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