

# Epidemiological study of paediatric traumatic brain injury in Brazil

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## ABSTRACT

**Background:** Traumatic brain injury (TBI) has a high economic and social impact on the family dynamics, particularly among children. High-quality and comprehensive epidemiological studies about TBI in this population are limited worldwide, specifically in Latin America. Therefore, this study aimed to elucidate the epidemiology of TBI among children in Brazil and its effects on the public health system.

**Methods:** This epidemiological (cohort) retrospective study collected data from the Brazilian healthcare database between 1992 and 2021.

**Results:** The mean annual volume of hospital admission (HA) due to TBI in Brazil was 29,017. Moreover, the incidence of TBI in the paediatric population was 45.35 admissions per 100,000 inhabitants/year. Furthermore, approximately 941 paediatric hospital deaths per year were caused by TBI, with an in-hospital lethality rate of 3.21%. The average annual financial transfer for TBI was 12,376,628 USD, and the mean cost per admission was 417 USD. In addition, the mean length of hospital stay was 4.2 days. Notably, the length of stay in the hospital was longer among males, Afro-Brazilians patients and individuals aged 15–19 years.

**Conclusion:** Paediatric TBI is an important public health issue worldwide with high social and economic costs. The incidence of paediatric TBI in Brazil is similar to that in developing countries. Moreover, male predominance (2.3:1) was observed in relation paediatric TBI. Notably, during the pandemic, the incidence of paediatric HA has decreased. To the best of our knowledge, this is the first epidemiological study that specifically evaluates paediatric TBI in Latin America.

## 1. Introduction

Traumatic brain injury (TBI) is defined as a change in brain function or the presence of other brain pathologies caused by an external force.<sup>1</sup>

Approximately 69 million individuals present with TBI from all causes annually worldwide, and approximately 81% of cases are mild.<sup>2</sup> Among all types of trauma, TBI has the highest risk of mortality or permanent functional loss.<sup>3</sup> This finding is particularly true in developing countries, which have recorded 89% of trauma-related deaths.<sup>4</sup>

TBI has a high economic and social impact on the family dynamics of patients.<sup>4,5</sup> Studies conducted in the US revealed that >36% of health care costs are allocated within the first 6 months after TBI, and almost 53% are allocated within the first year.<sup>4,5</sup> Severe TBI, which requires more hospital resources and can cause significant sequelae requiring more intense post-acute rehabilitation programmes, has high economic costs.<sup>6</sup> This is exemplified by the high incidence of neuropsychological

damage in the long-term follow-up of children with severe TBI.<sup>7</sup> These sequelae are occasionally not evident, and the society is not aware of this issue. Hence, TBI is referred to as the silent epidemic.<sup>1</sup>

High-quality and comprehensive epidemiological studies about TBI are limited worldwide, particularly in developing countries.<sup>4</sup> Consequently, there is no sufficient management strategy for decreasing the incidence of TBI based on its causes and risk groups.<sup>8</sup> Therefore, inadequate monitoring in some subgroups, including children, is even more serious because of the emotional, social and economic impact of severe TBI sequelae.

The incidence of paediatric TBI varies worldwide. Dewan et al<sup>9</sup> performed a comprehensive literature review in 2016 by searching global epidemiology reports, and they found that the incidence of paediatric TBI is diverse and varies significantly across countries. The incidence rate ranged from 47 to 280 per 100,000 children.

Thus, because of the lack of epidemiological data about head trauma

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in children and its importance on morbidity and mortality, this study aimed to elucidate the epidemiology of TBI among children and its impact on the Brazilian Unified Health System (SUS).

## 2. Materials and methods

This epidemiological (cohort), retrospective and descriptive study collected data from the Hospital Information System (SIH)/SUS of the Information Technology Department of The United Health System (DATASUS) in December 2021.

Data regarding the incidence of paediatric (<19 year-old) TBI between 1992 and 2020 were extracted using International Disease Classification, 9th revision (ICD-9) from 1992 to 2007 and ICD, 10th revision (ICD-10) from 2008 to 2020.

The database search was performed using International Disease Classification, 9th revision (ICD-9) codes as the reference for disease classification, which were available from 1992 to 2007. As recommended by the World Health Organization, to identify TBI cases, the following keywords were used: 'Fracture of Skull and Face', 'Concussion', 'Intracranial injury, except that associated with fracture of skull and concussion' and 'Injury of nerves and optic pathways and other cranial nerves'.<sup>10</sup>

From 2008 to 2020, the search was based on ICD-10 codes, and the following terms were selected from a list of diagnoses: 'skull and facial bone fracture' and 'head injury'. By selecting the appropriate fields, we collected data about approved hospital admission (HA) authorisation (AIH), age group, sex, ethnicity, total cost in Brazilian real (Brazilian currency), mean cost per AIH, mean length of hospital stay (LOS), deaths, annual mortality rate and in-hospital lethality. The annual incidence of paediatric TBI was calculated based on the paediatric and total populations in each year in DATASUS. The total cost (USD) was calculated using the mean dollar exchange rate in each year in Brazil.

Data obtained from DATASUS were recorded in Microsoft Excel, with subsequent validation to identify and correct possible typing errors that could affect results.

Authors followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. As DATASUS is a public domain database, the need for ethical approval was waived.

## 3. Results

Data obtained via SIH/SUS were used to calculate the incidence rate between 1992 and 2020, with a significant decrease after 1997 (Graphic 1).

From 2008 to 2020, the mean annual volume of hospital admissions (HA) caused by TBI was 29,017 in Brazil. With consideration of a mean total population of 200,932,535, the incidence (including adults) was 14.5 admissions per 100,000 inhabitants per year. The mean incidence in

the paediatric population was 45.35 admissions per 100,000 children per year, with consideration of a mean child population of 63,922,497.

Approximately 941 paediatric hospital deaths were caused by TBI per year in this period, which resulted in an in-hospital mortality rate of approximately 3.26% in children. Based on in-hospital mortality and population data, the in-hospital paediatric mortality was 0.47 deaths per 100,000 paediatric inhabitants per year. Moreover, the in-hospital mortality was 1.47 deaths per 100,000 inhabitants per year according to the global Brazilian population.

The average annual financial transfer for TBI was 30,755,255 Brazilian real or 12,376,628 USD, and the mean cost per admission was 1074 Brazilian real or 417 USD. The mean LOS was 4.2 days (Table 1).

Table 2 shows the case distribution according to race and ethnicity, with mean values from 2008 to 2020. In terms of race, 8973 (30.94%) were whites; 695 (2.39%) were Afro-Brazilians; 9157 (31.55%) were of mixed race; 291 (1%) were asians; 55 (0.19%) were indigenous; and 9835 (33.91%) did not inform about their race and ethnicity. Regarding age, 2513 (8.66%) patients were aged <1 years; 5452 (18.79%) were of 1–4 years; 5053 (17.42%) were of 5–9 years; 4795 (16.53%) were of 10–14 years; and 11,194 (38.58%) were of 15–19 years. In total, 20,258 and 8750 were males and females, respectively, with a ratio of 2.3:1. The 15–19-year-old (1466.56 Brazilian real and 523.81 USD), male (1143.33 Brazilian real and 408.37 USD) and Afro-Brazilians (1216.66 Brazilian real and 434.8 USD) groups had the highest mean cost per admission.

## 4. Discussion

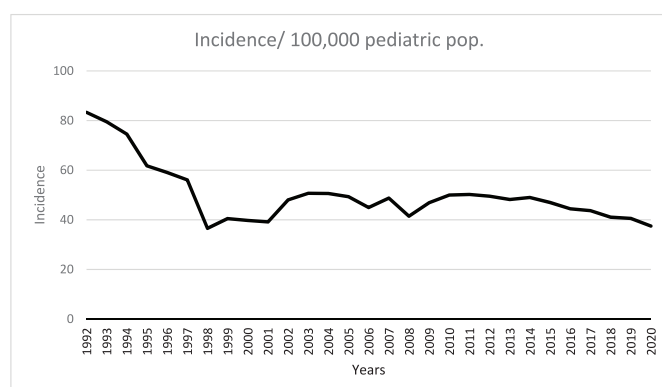
This study aimed to characterise the demographic, social and economic profiles of the paediatric population with TBI in Brazil, the larger and populous country in Latin America. Data were extracted from the SIH/SUS–DATASUS, which is a database managed by the Health Department and supplied by public units that send information about HA to municipal and state managers.<sup>11</sup> The database includes all information about patients admitted to the Brazilian Public Healthcare System (all Hospitals and health institutions).

DATASUS is a data repository that was created in 1991, and it is supported by a network of systems, including SIH/SUS.<sup>12</sup> DATASUS was developed within the last 30 years and has enabled more integration among the health services and healthcare workers. In this context, the SIH/SUS has included more data, facilitating the generation of reports and more detailed collection of records,<sup>13</sup> especially since 2008. Approximately 71.5% of the Brazilian people rely solely on the SUS as a healthcare service. In most cases of major traumas, patients are first presented to a public hospital and then referred to private services if they have health insurance. Therefore, the public health system covers at least 70% of TBI treatment cases.<sup>14</sup>

In this study, the incidence of paediatric TBI was 45.35 per 100,000 children/year and 29,017 HAs per year.

Notably, the incidence of paediatric TBI varies worldwide. Dewan et al.<sup>9</sup> performed a qualitative review of global paediatric TBI, and the results of their study revealed that the incidence varied worldwide, ranging from 12 in Sweden to 486 in Australia per 100,000 children/year. In the US, TBI affects 475,000 children annually, and it causes over 2600 TBI-related deaths, 37,000 hospitalisations and 435,000 emergency department (ED) visits. The incidence of hospitalisation is 70 cases per 100,000 children/year in the US.<sup>15,16</sup> In Germany, Bruns et al reported 10.2 million hospitalisations, 458,844 TBI cases and an incidence of 687 cases per 100,000 children/year between 2014 and 2018, with a mortality rate of 0.67 cases per 100,000 children/year.<sup>17</sup>

The incidence reported in the present study was lower than that reported in the US, Germany and Australia (countries with high Health Quality and Access). Apart from the Brazilian Health Quality, this can be explained by the fact that our study did not register pre-hospital deaths and ED visits but only registered HAs. Notably, most epidemiological studies of paediatric TBI do not distinguish between admissions, ED visits or pre-hospital deaths.



Graphic 1. Incidence rate of TBI/100,000 children in Brazil from 1992–2020.

**Table 1**  
Epidemiological aspects of traumatic brain injury in Brazil in the paediatric population, 2008–2020.

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean
<b>Hospital Admissions</b>														
Total Incidence (/100,000 pop.)	27,530	30,924	31,464	31,875	31,697	31,644	31,924	30,320	28,422	27,667	25,713	25,115	22,924	29,017
Total Cost (US\$)	14.51	16.14	16.49	16.56	16.34	15.74	15.74	14.82	13.79	13.32	12.29	11.92	10.80	14.50
Mean Cost per admission (US\$)	41.45	46.90	50	50.21	49.50	48.18	49.01	46.97	44.45	43.71	41.07	40.57	37.48	45.35
Pediatric Incidence (/100,000 pop.)	11,860,741	13,525,377	16,703,092	18,642,935	17,004,742	15,891,270	15,148,789	10,285,189	9,882,237	10,372,575	8,317,565	7,474,740	5,786,908	12,376,628
Mean Length of Hospital Stay (days)	4.2	4	4.2	4.1	4.3	4.3	4.3	4.2	4.4	4.2	4.2	4	4	4.18
Hospital Deaths	1072	1127	1048	1007	1070	1093	1107	983	906	825	697	642	651	941
In-Hospital Pediatric Mortality (/1000 pop.)	0.0056	0.0058	0.0054	0.0052	0.0055	0.0054	0.0054	0.0048	0.0043	0.0039	0.0033	0.0030	0.0020	0.0047
In-Hospital Total Mortality (/1000 pop.)	0.016	0.017	0.016	0.015	0.016	0.016	0.016	0.015	0.014	0.013	0.011	0.010	0.010	0.014
In-Hospital Lethality (%)	3.89	3.64	3.33	3.15	3.37	3.45	3.46	3.24	3.18	2.98	2.71	2.55	2.83	3.21

In a review of the global epidemiology of TBI in children, Thurman reported the incidence of 97 in Finland (age range of studied group, 0–19 years), 91 in Australia (0–14 years) and 973 in New Zealand (0–14 years) per 100,000 children.<sup>13</sup> Notably, these rates were age-adjusted to US population of 2000 aged 0–19 years.<sup>14</sup> Asian data revealed an incidence of 475.8 in Korea (0–19 years old),<sup>18</sup> and the incidence in China could not be found in any recent articles.

Unfortunately, data regarding children with TBI from low- and middle-income countries are limited, as reported by Dewan.<sup>9</sup> Regarding Latin American, causes of TBI among children in Argentina were highlighted in a 1999 study with 2492 children; of these, 33.5% were 0–2 years old, 43.8% were 3–9 years old and 22.7% were 10–15 years old. Falls were found to be the main cause of TBI in children aged <3 years, and road traffic injuries (RTI) were the leading cause of TBI among older children. The incidence of 566 TBI cases per 100,000 children and a corresponding mortality rate of 4.65 per 1000 TBI cases were reported in the relevant literature; this incidence is 2.97 times higher than that of the international average.<sup>19</sup>

The International Multicenter Study of Head Injury in Children compiled data of all children from Argentina, Brazil, France, Hong Kong and Spain who were aged 0–15 years, visited the emergency room and were hospitalised. Of these children, minor injuries were observed in 56%, moderate in 39% and severe in 5%, with a case-fatality rate of 1.6%. Moreover, 61% children were males, and most children (55%) were 0–4 years old.<sup>20</sup>

We reported a mean cost per admission (MCPA) of 417.88 USD. However, we observed a decrease in the MCPA from 584.87 to 252.43 from 2011 to 2020, without drastic changes in internal health affairs in Brazil. Thus, the devaluation of the Brazilian currency (real) very plausibly caused it.

Only few studies have assessed the LOS in paediatric TBI. Schneier et al evaluated data about TBI hospitalisation in the US in 2000. The results of their study revealed that the mean LOS was  $4.5 \pm 12.9$  (median: 2) days, with a mean cost of  $20,325 \pm 62,112$  USD.<sup>15</sup> Notably, in the present study, the mean LOS was 4.2, and the cost was 417.00 USD per children. This value was found in the health system and was not the actual amount spent by the health system to treat the children.

Male children were 2.3 times more affected by TBI than female children in Brazil. This result is in accordance with that of other studies,<sup>21,22–24</sup> except for a Malaysian study about children with mild TBI who were admitted to the hospital from 1998 to 2021, which revealed a male-to-female ratio of 0.48.<sup>25</sup>

The distribution of TBI in children is bimodal, with a high incidence observed in extremely young (0–3) and older<sup>16,21,22,25</sup> children.<sup>9</sup> Our study showed that 38.58% of children aged between 15 and 19 years and 27.45% aged between 0 and 4 years were affected. This distribution is relative to trauma mechanism, which is caused by falls in younger children and RTI in older children.<sup>26</sup>

The volume of HA cases per year was constant from 2008 to 2019. In 2020, there was a decrease in HA possibly caused by the coronavirus disease 2019 pandemic and lockdown policies.<sup>27</sup> Hence, the incidence of HA caused by RTI could have decreased due to a lower number of people doing everyday activities.<sup>16</sup>

Some studies reported a decrease in the volume of HA attributed to TBI among children during the coronavirus disease 2019 pandemic.<sup>28</sup> The volume of HA caused by abuse-related trauma in the US decreased. However, a higher severity was observed.<sup>29</sup> Other studies reported a higher volume of HA caused by abuse-related head trauma based on the study of Sidpra et al, which was performed in the United Kingdom.<sup>30</sup>

Unfortunately, DATASUS does not provide information about the causes of TBI in children, and the mechanism of paediatric TBI varies with population and age groups. Generally, motor vehicle collisions (6%–80%) and falls (5%–87%) account for the majority of injuries, followed by abuse and other forms of non-accidental trauma (2%–12%) and sports-related injury (1%–29%).<sup>15</sup>

Regarding Brazilian TBI data, De Almeida reported that the incidence

**Table 2**

Epidemiological aspects of traumatic brain injury in Brazil, according to age group, sex and ethnicity. Mean annual values from 2008–2020.

	Hospital Admissions	Incidence (/100.000 pop)	Total cost (US\$)	Cost per Admission (US\$)	Mean Length of Hospital Stay (days)	Deaths	Mortality (%)
<b>Age Group (years)</b>							
<1	2513	85.88	646,036.51	256.65	3.3	48.38	1.93
1–4	5452	45.19	1,333,104.94	244.49	3.1	76.69	1.41
5–9	5053	31.58	1,432,510.92	283.46	3.4	72.69	1.44
10–14	4795	28.56	1,766,668.35	368.36	4.2	124.76	2.60
15–19	11,194	65.38	5,863,794.56	523.81	5.3	621.76	5.55
<b>Sex</b>							
Male	20,258	61.21	8,273,246.51	408.37	4.4	736.23	3.63
Female	8750	27.5	2,767,868.79	316.30	3.7	208.07	2.38
<b>Ethnicity</b>							
White	8973		3,499,463.12	389.96	3.5	224.84	2.51
Afro-Brazilians	695		302,102.45	434.48	4.6	26.07	3.75
Mixed Race	9157		3,663,720.12	400.07	4.4	303.15	3.31
Asians	291		108,549.43	371.93	4.6	10.76	3.69
Indigenous	55		19,095.21	341.92	4.4	2.23	3.99
No Information	9835		3,448,184.96	350.69	4.6	377.23	3.84
<b>Total</b>	<b>29,009</b>	<b>44.70</b>	<b>11,041,115.30</b>	<b>380.60</b>	<b>4.2</b>	<b>944.30</b>	<b>3.26</b>

of TBI was 65.7 admissions per 100,000 inhabitants/year from 2008 to 2012; this incidence is higher than that in children. Meanwhile, the hospital mortality was 5.1 per 100,000 inhabitants/year, and the case-fatality rate was 7.7%. Our casuistry indicated that the mortality rate was 3.26%.<sup>31</sup>

## 5. Limitations

The current study had several limitations. Data in DATASUS were incomplete. That is, 33.9% of ethnicity data were not available. Thus, the diagnosis and its ICD classification might vary from those obtained by healthcare workers. Moreover, variations in HA costs may reflect differences in dollars and devaluation of the Brazilian currency. Other factors may influence mortality rates. These include the lack of data about death at the site of trauma, during transportation to emergency units and after hospital discharge in addition to the fact that children were admitted in the private health care system (minority). Moreover, the study was descriptive in nature and was a snapshot in time, not a longitudinal analysis.

The acquisition of population-based data about TBI is a key component in the appropriate management of trauma in children. DATASUS can provide substantial data about several diseases. Data about the lesion aetiology, which is functional information and is essential to epidemiological studies about traumatic injuries, were not available.

## 6. Conclusions

Paediatric TBI is an important public health issue in different countries worldwide, particularly in Brazil. Moreover, it is associated with high social and economic costs. The incidence of paediatric TBI in Brazil is similar to that in developing countries, and other studies reported male predominance. During the pandemic, the volume of paediatric HA has decreased. To the best of our knowledge, this is the first nationwide epidemiological study about paediatric TBI in Brazil.

## Statements and declarations

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## Credit author statement

**Leandro Cândido de Souza:** Conceptualization, Data Curation, Investigation, Writing – Original Draft Preparation; **Thiago Mazzu Nascimento:** Formal Analysis, Writing – Original Draft Preparation; **Jaqueline Garcia de Almeida Ballesterro:** Data Curation, Formal Analysis, Writing – Original Draft Preparation; **Ricardo Santos de Oliveira:** Investigation, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Matheus Fernando Manzolli Ballesterro:** Conceptualization (Lead), Formal Analysis, Investigation, Methodology, Project Administration, Supervision, Writing – Original Draft Preparation.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.wnsx.2023.100206>.

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## Abbreviations list

AIH: hospital admission authorisation  
 DATASUS: Information Technology Department of The United Health System  
 ED: emergency department  
 HA: hospital admissions  
 LOS: length of hospital stay  
 MCPA: mean cost per admission  
 RTI: road traffic injuries  
 SIS: Hospital Information System  
 STROBE: Strengthening the Reporting of Observational Studies in Epidemiology SUS - Brazilian Unified Health System  
 TBI: Traumatic brain injury