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# A Population-Based Study of the Incidence, Medical Care, and Medical Expenditures for Pediatric Traumatic Brain Injury

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## Abstract

**Background:** Traumatic brain injury (TBI) is one of the leading causes of pediatric trauma morbidity and mortality around the world. However, limited research exists regarding disparities in the incidence of TBI and medical care seeking behaviors and medical expenditures for TBI, particularly using population-based and nationally-representative data.

**Materials and Methods:** The present study used the Medical Expenditure Panel Survey (**MEPS**) Panels 9−19 (2004−2015) to provide nationally-representative estimates for the civilian, non-institutionalized U.S. population. We examined differences in TBI incidence and associated medical care seeking behaviors and expenditures in relation to individual and family sociodemographic characteristics.

**Results:** From a total of 50,563 children in the MEPS Panels 9−19, we identified 449 children with TBI. For 82% of these children, medical treatment was sought. The estimated annual total expenditure associated with pediatric TBIs nationally was approximately $667 million, with mean expenditures per TBI being $1,532 and family out of pocket expenditures accounting for 8.3% of total expenditures. Race/ethnicity was the only significant factor associated with both medical care seeking behavior and total expenditures.

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Author Contributions
Jiabin Shen conceptualized the study, led the implementation of study protocol, drafted the manuscript, and finalized the submission. Junxin Shi and Cheng Chen wrote the SAS programs for data analysis. Jennifer Cooper made significant contribution to the section on health disparities. H. Gerry Taylor and Henry Xiang contributed to overseeing the study implementation and revising the manuscript. All authors approved the final version of the manuscript.

Disclosure
All authors declare no conflict of interest.

Supplementary Materials
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**Conclusions:** The present study is among the first to compare pediatric TBI-related medical expenditures among different sociodemographic groups in the U.S. Our findings can inform future intervention research and policy-making from the perspectives of both epidemiological and behavioral sciences.

**Keywords**

Children; Traumatic brain injury; Expenditure; MEPS; Burden

## Introduction

Traumatic brain injury (*TBI*) is a recognized threat to the health of the U.S. population. Labeled as the 'silent epidemic', the Centers for Disease Control and Prevention (*CDC*) estimated that the TBI incidence rate rose significantly in the ten years from 2001−2010 from 521.0 per 100,000−823.7 per 100,000, respectively.[1] The World Health Organization estimated in 2007 that by 2020 TBI would become the primary cause of death and disability around the world.[2] TBI is particularly a health threat to children[1] because a childhood TBI may exert a lasting disruptive effect on the still-developing brain and damage its ability to form new neural connectivity for the acquisition of new skills throughout life.[3] According to the **CDC**, pediatric TBIs are now a leading cause of acquired disability in U.S. children; every year, an estimated 700,000 U.S. children experience a TBI.[1] This threat is especially critical for younger children, with the CDC reporting that TBI-related emergency department visits for children less than four years increased by a dramatic 50% from 2008 to 2010, from 1374.0 to 2193.8 per 100,000, respectively.[3] Importantly, the burden of TBI-related care can also exert a deleterious effect on society and the financial stability of affected families.[4–8]

Therefore, both researchers and policy-makers must gain a comprehensive understanding of the disparities in incidence, healthcare-seeking behaviors and expenditures associated with a pediatric TBI. The risk of disabilities and need for recovery services following a pediatric TBI leave both society and survivors' families with unexpected economic burdens.[1] The CDC estimated that the economic costs of TBI in 2010 were $76.5 billion, with $11.5 billion in direct medical costs and $64.8 billion in indirect costs such as lost productivity.[1] For individual families, personal bankruptcy after a TBI is not uncommon in the United States.[9]

However, previous research on the economic burden suffers from a significant limitation. Most studies, including the CDC report, used only hospital administrative records to generate estimates. This approach raises two issues. First, it dramatically underestimates the societal and family economic burden related to TBI because costs associated with out-of-pocket expenditures and medical visits to physician offices and other medical settings are not considered. The CDC's 2014 special report to Congress,[1] as well as a recent 2016 study, confirmed this hidden cost and disclosed that inpatient expenditures only account for a limited portion of the economic burden associated with pediatric TBI.[10] The only study on pediatric TBI-related costs that addressed this limitation found that expenditures for TBI related services in children were $77.9 million per year. However, that 2004 report narrowly focused on moderate to severe pediatric TBIs, and did not specifically address the family economic burden or compare the TBI-related costs to all medical costs on a national level.[11] Second, hospital data usually fail to capture healthcare-seeking behaviors, namely the fact that medical care is never sought for some children with TBI. Both issues could be solved by using a population-based nationally representative database that captures all self-reported TBI events as well as all medical encounters and associated expenditures. Considering the vulnerability of children to TBI and the significant increase in the incidence of recognized pediatric TBI in the past decade, now is a critical time to examine the healthcare-seeking behaviors and the economic burden associated with pediatric TBI, and also to evaluate how these differ across various sociodemographic groups. Disparities in the economic burden incurred as a result of the medical service costs associated with pediatric TBIs from multiple payment sources have not been explored.

Furthermore, most existing research on pediatric TBI has failed to examine disparities in medical care seeking behaviors and expenditures among different sociodemographic subpopulations.[11] Defined as "*a particular type of health difference that is closely linked with economic, social, or environmental disadvantage*"[12], health disparities are widespread in the United States.[13] Sociodemographic factors such as race, ethnicity, and socioeconomic status are strongly associated with child health[14], but health disparities linked with these factors are also preventable with effective strategies such as evidence-based policy-making.[13] Furthermore, in the field of trauma care, researchers have identified additional risk factors for different health outcomes such as patient insurance status.[15] Considering the dramatic increase in the recognition and number of pediatric TBIs in the past decade, policy-makers are in critical need of the latest national estimates of the societal and family economic burdens associated with pediatric TBI and how this burden differs among sociodemographic subpopulations. Identification of factors associated with increased burden may help guide the design of systems to better meet the needs of children with TBI and improve their outcomes.

The objective of our study was to examine disparities in the incidence of and healthcare-seeking behaviors and expenditures associated with pediatric TBIs in the United States. The present study examined sociodemographic factors that might be associated with healthcare seeking behaviors and medical expenditures based on previous literature, such as child race/ethnicity, socioeconomic status, and type of health insurance (private or public) after accounting for pre-injury disability status.

## Methods

### Data source

The current study used the Medical Expenditure Panel Survey (*MEPS*) Panels 9−19 (2004−2015). The MEPS is co-sponsored by the Agency for Healthcare Research and Quality (*AHRQ*) and the National Center for Health Statistics. The MEPS is conducted to provide nationally representative estimates of health care use, medical expenditures, sources of payment, and health insurance coverage for the civilian, non-institutionalized U.S. population. The panel design of the survey, which features five rounds of interviewing, covers two full calendar years.

During the course of their participation in MEPS, participants are asked to track their health care expenditures, including bills and receipts for care. They also provide sociodemographic and health insurance coverage information. Some expenditure data are verified and supplemented by records from medical providers, health insurers, and pharmacies. This procedure is used to provide estimates for care delivered under reimbursement arrangements or through public clinics. Furthermore, the MEPS defines total expenditures as the sum of payments for medical care services, which include out-of-pocket payments (defined as 'family expenditures' in this paper) and payments made by private and public insurance plans, including Medicare and Medicaid. The MEPS does not include over-the-counter medication payment or medical expenses arising from alternative treatments such as acupuncture, nor does it consider indirect costs such as time taken off from work. The MEPS compensates for missing values by single imputation, providing missing values with existing expenditure data either from the MEPS Household Component or the MEPS Medical Provider Component.

## Study population

The study population was children with a traumatic brain injury (18 years and younger). According to the CDC,[1] the following International Classification of Diseases, 9 Revision, Clinical Modification (ICD-9-CM) codes define TBI cases: codes 800−854 indicate intracranial injury in a Clinical Classification Code variable (CCCODEX = 233). ICD-10-CM was not adopted yet for the MEPS Panels covered in the present study. MEPS surveyors went door-to-door to the sampled households and interviewed adults in each household regarding the health history of all members of the household, including their children's history of TBI. The MEPS Panels 9−19 (2004−2015) included 451 pediatric TBI cases (449 pediatric TBI patients), representing 453,219 pediatric TBI cases on the national level (Table 1). Note that these ICD-9-CM codes include TBIs of varying injury severities but the severity information in MEPS was not sufficient to classify the included TBI cases into meaningful subgroups for analysis. Specifically, instead of the three-digit ICD-9-CM codes, we originally planned to use the fully-specified five-digit codes to compute the head Abbreviated Injury Scale (**AIS**) score (as a measure of injury severity) onsite at the AHRQ Data Center. However, after examining the data at the AHRQ Data Center, we found that almost all sample data clustered around the Head AIS score of 2, with few patients in other groups, rendering using the Head AIS score impractical as a valid injury severity measure for estimating how TBI severity influences family and insurance-paid medical expenditures. Consequently, we used the three-digit codes (which are publically available) instead due to the lack of fully-specified five-digit codes.

## Data analysis plan

SAS 9.4 software was used to perform all data analyses. All analyses accounted for the complex sampling design and weighting structure of the MEPS. In the MEPS database, weighting variables are provided for generating MEPS estimates of totals, means, medians, percentages, and rates for persons and families in the civilian, non-institutionalized U.S. population.

First, we applied survey data analysis methods to calculate national estimates of the number of children with TBI, a two-year accumulative rate (with the total U.S. child population during that period as the denominator), the proportion seeking medical treatment, the total expenditure, and average expenditures per TBI.

Next, we calculated the mean and median medical service expenditures per pediatric TBI. All expenditures captured in this calculation were generated during the same two-year period for that specific panel, although those expenditures occurred at the end of the survey period may not be captured due to the closure of that specific survey period. A bootstrapping approach was used to obtain a 95% CI for median medical service expenditures associated with the treatment and recovery of a pediatric TBI. The bootstrapping approach was selected because medical service expenditures do not follow a normal distribution. The following four-step approach was used in performing the boostrapping computation: (1) counted expenditures in each sub-group; (2) randomly selected a same-sized sample with replacement and repeated 2000 times (2000 bootstrap samples); (3) for each random sample, calculated weighted total expenditure; and finally (4) assembled results from all 2000 bootstrap samples and calculated the median as the point estimate and 2.5 and 97.5 percentiles as the 95% confidence interval. Specifically, family expenditures were calculated as the amount of out-of-pocket expenses related to pediatric TBIs; insurance-paid expenditures were calculated as the amount of insurance-paid expenses related to pediatric TBIs; and finally, total expenditures were calculated as the sum of family and insurance-paid expenditures related to pediatric TBIs. Data in the present study covered 12 years (2004−2015), so we used an inflation adjustment rate to adjust all of the expenditures to 2015 values. We used the “Inflation Calculator,” available on the U.S. Department of Labor Statistics official website, to make these adjustments. All medical expenditure data were further examined across groups defined by pre-injury disability status, sociodemographic factors (child age, child sex, child race/ethnicity, family income, parental education, family marriage status, and child type of health insurance), type of service (ambulatory, emergency department, hospital inpatient, home health, and prescribed medicines), and source of payment (private insurance, out-of-pocket, Medicare, Medicaid/CHIP, and others).

Finally, we fit a multivariable logistic regression model to examine how age, sex, race/ethnicity, family marital status, parents’ education level, family poverty status, and insurance coverage status were associated with families’ likelihood of seeking medical care after a child’s TBI. Pre-TBI disability status served as a covariate in these models. Further, a multivariable log linear-regression model evaluated the association between the medical expenditure amount and sociodemographic variables among those patients with medical expenditures greater than zero. Similarly, sociodemographic variables including age, sex, race, family marital status, parental education level, family income, and health insurance status were simultaneously entered into the regression model as independent variables while pre-TBI disability status was a covariate. The present study adopted a conservative “rule of thumb” approach to estimate required sample size for the regression models[16], which requires at least 30 participants for each independent variable added to the regression model. The present analysis plan included eight independent variables, hence requiring at least 240 participants. Furthermore, in consideration of potential bias resulting from truncated follow-up cases in the final round of MEPS interviews, we conducted a sensitivity analysis comparing results between samples with and without Round 5 data and found similar results (see Supplementary Table B). Therefore, the present study retained data from all five rounds of MEPS interviews.

### Institutional review board (IRB)

This study was reviewed by the local institutional IRB, which determined that review was not required because the project did not involve human subjects.

## Results

### Incidence proportion for pediatric TBI

As shown in Table 1, a total of 50,563 children (18 years and younger) were identified in the MEPS Panels 9−19 (2004−2015). In total, there were 449 children with at least one TBI, accounting for 451 pediatric TBI cases (two children had two TBIs each during their two years of participation in MEPS). Of these 451 pediatric TBI cases, 82% sought medical treatments. The national estimates of pediatric TBIs were 453,220 annually from 2004−2015. This sample represents a 1.22% annual incidence of pediatric TBI in the United States. Table 2 presents the distribution of pediatric TBIs by various sociodemograhic factors. The following variables were associated with the incidence of pediatric TBI, with odds ratio (OR) greater than 1 indicating higher incidence in those groups and OR smaller than 1 indicating lower incidence: Age of 10−14 yrs (OR = 1.47) and 15−17 yrs (OR = 1.85) versus 0−4 yrs; female sex (OR = 0.47) versus male; black (OR = 0.58), Hispanic (OR = 0.56), and Asian (OR = 0.51) versus white/other race; families with middle incomes (OR = 0.62) and low incomes (OR = 0.61) versus high incomes; and those who were uninsured (OR = 0.53) versus privately insured.

### Medical care seeking behaviors related to pediatric TBI

Overall, 82% of children with a TBI sought medical treatment following their injury. Medical care seeking behavior was also analyzed in association with sociodemographic characteristics as presented in Table 3. Multivariable logistic regression analyses (Table 4) indicated that the only significant factor associated with receiving medical care after pediatric TBI was child race/ethnicity, after controlling for all other available socio-demographic factors. Children whose parent identified them as Black or African American were less likely to receive medical treatment after a pediatric TBI than children of other racial/ethnic backgrounds (OR = 0.29, 95%CI: 0.12 – 0.69 in comparison to children of White or “other” race).

### Medical expenditures related to pediatric TBI

**Overview—**Based on the MEPS data, the estimated annual total expenditure was $666,741,567, with median expenditure per TBI being $383 and mean expenditures per TBI being $1,532. Within this total amount, family expenditure (out-of-pocket expenses) accounted for 8.3% and insurance-paid expenditure (private or public insurance) accounted for 91.7%.

**By sociodemographic factors—**The proportions of pediatric TBI events associated with any medical expenditures during the study period were further broken down by various demographic factors in Table 3. For total expenditure, the population groups with relatively higher median expenditures were females ($434), ages 15 to 17 ($442), non-Hispanic White/other races ($426), families with both parents ($459), families with parental education level at high school ($474), families with high-income levels ($474), families with private insurance ($432), and children without disability ($383).

**Family expenditures:** The population groups with relatively higher median family expenditures were families of patients who were females ($6), ages 5 to 9 ($22), Asians ($16), families with both parents ($19), families with parental education level being college and higher ($19), families with high-income levels ($41), families with private insurance ($27), and children with disability ($12) with high variability in the interquartile ranges of values (Table 3).

**Insurance-paid expenditures:** The population groups with relatively higher median insurance-paid expenditures were females ($305), ages 0 to 4 ($313), non-Hispanic white/other races ($342), families with both parents ($335), families with parental education level at high school ($422), families with high-income levels ($338), families with private insurance ($315), and children with disability ($370) again with high interquartile range variability (Table 3).

**By type of service and source of payment—**Of the total medical expenditure, hospital inpatient services comprised 47.9%, followed by emergency department services (36.7%), and 13.8% for ambulatory services, with home health and prescribed medicines taking up the remaining 1.6% (Table 5). The most significant source of payment was private insurance, which accounted for 70.9%, while Medicaid/Medicare accounted for 12.6% of expenditures, and out-of-pocket expenditures (i.e.,family expenditures) accounted for 8.3%. The remaining 8.2% in the 'Other' category included payments from the Department of Veteran Affairs, other federal, state, and local sources as well as various unclassified sources as detailed in the footnote of Table 5.

**Log-linear regression analyses—**Finally, multivariable log-linear regression models examined how demographic factors were associated with the total, family, and insurance-paid medical expenditures for pediatric TBI-related services between 2004 and 2015. The only significant factor associated with *total expenditures* was race/ethnicity (Table 4), where patients identified as Black or African Americans incurred 78% less on total medical expenditures related to pediatric TBI than other groups.

Three factors emerged as significant factors associated with *family expenditures* related to pediatric TBI. Specifically, families who identified their children as Black or African American spent 65% less out-of-pocket than families who identified their child as White/other race. Families with only public insurance spent 88% less out-of-pocket than those with private insurance. Additionally, single parents of a child with a TBI spent 63% less out-of-pocket than two-parent households.

Furthermore, race/ethnicity emerged as the only significant factor associated with insurance-paid expenditures related to pediatric TBI. Specifically, families who identified their child as Black or African American had 73% less insurance-paid expenses compared to families who identified their child as White/other race. Similarly, families who identified their child as Hispanic had 59% less insurance-paid expenses compared to families who identified their child as White/other race.

## Discussion

The present study utilized 12-years of population-based survey data to examine the incidence of pediatric TBI and medical expenditures and medical care seeking behaviors associated with pediatric TBI in the United States. The results showed an overall national 1.22% incidence proportion of pediatric TBI per year. Such an annual incidence proportion is significantly higher than the incidence proportion reported by CDC in 2010[1] but is consistent with the trend observed in the past two decades where the pediatric TBI incidence has been steadily increasing annually. On the one hand, the present study found that male adolescents have a higher incidence proportion than their younger and female peers. This finding was not surprising and is consistent with prior research.[17] Adolescence is a developmental period when individuals are increasingly likely to engage in high-risk behaviors[18–22] such as reckless driving[23, 24] that might result in a TBI, especially among male adolescents.[25] Such findings, however, should be interpreted with caution since the present study lacked sufficient data on injury mechanisms to empirically substantiate this possibility.

On the other hand, children who live in families with higher socioeconomic status (*SES*, including parental education, family income) had a higher incidence proportion of pediatric TBIs compared to their counterparts with lower SES. We propose two possible explanations for this finding. First, families of lower SES may have been less likely to report a brain injury event. The database we used in the present study (MEPS) is from a population-based survey, which relies on surveyors going into individual households and collecting data through interviews and/or paper-based questionnaires. The reporting of pediatric TBI in this database, therefore, was dependent on patients and families recognizing the symptoms and criteria for a TBI. Previous research suggests that higher educational level and annual household income are significant factors associated with being aware of brain injury symptoms.[26] Hence, families with higher SES may be more likely than those with lower SES to recognize post-TBI symptoms and to report them to the MEPS surveyors, resulting in a reporting bias of pediatric TBI between families of higher and lower SES.

A second possibility is that individuals with higher levels of perceived safety/security are more likely to have higher levels of “perceived invulnerability,” resulting in more risk-taking behaviors (which might lead to a TBI) than those with lower levels of perceived safety/security.[27, 28] Therefore, children living in families with higher SES may be more likely to take risky behaviors leading to TBIs because of their ‘false’ confidence in safety due to the availability of protective factors such as accessible healthcare and funds for out-of-pocket medical expenses, as well as their false sense of invulnerability that is typical during adolescent development.

The pediatric TBI literature has suggested that medical care following the injury incident is critical for high-quality health outcomes.[29, 30] The present study found that following a pediatric TBI, the majority of families seek medical treatment for their child, although the percentage varies among different subgroups of the population in terms of gender, ethnicity, pre-injury disability, and family SES. Most significantly, even after controlling for all other available socio-demographic characteristics, we found that Black or African American children were still less likely to receive medical treatment compared to children of other racial/ethnic backgrounds. Due to the lack of information in the MEPS datasets, ascertaining the exact causes of this racial disparity in medical care-seeking behaviors following pediatric TBIs is not possible in the present study. However, previous studies on racial disparities in healthcare in general might shed some light on potential mechanisms. This body of research has identified barriers at multiple levels for racial/ethnic minority patients to obtain high quality healthcare, such as a lack of trust in healthcare providers and systems[31], a lack of effective communication between patients and clinicians[31], lower health literacy[32], and/or a lack of resources such as time, finances, and transportation to seek healthcare.[33]

In the particular case of pediatric TBI care, there has been little research in this area. However, Bazarian and colleagues[34] examined racial disparities in emergency department care for mild TBIs and found that African American patients were more likely (˜3 times) than Whites to be cared for by a resident rather than an attending physician. One possible explanation for this discrepancy might be that many African American patients live in urban areas in proximity to academic medical centers where there is a high likelihood of being treated by a resident. The same study also found that African American patients were less likely to return for follow-up care after discharge. Both the lack of specialized physician acute care and the lack of ability to access follow-up care could discourage African American patients initially from seeking medical care for a TBI, especially among those families with fewer resources for medical expenses.[35] Based on these findings, healthcare systems might be able to reduce racial disparities in healthcare for children with TBI by improving the accessibility of healthcare resources for families with limited resources, such as accommodating for flexible follow-up appointment schedules and offering alternative healthcare support in lieu of in-person visits, including affordable tele-medicine options via smartphones or low-cost online consultation. Future research is needed to evaluate such interventions and to identify the specific facilitators of and barriers to seeking medical care for children with TBI to promote the health outcomes and quality of life among all subgroups of children with TBI.

The estimated mean medical expenditure per child with a TBI during the 2-year MEPS reference period was $1,532, a number comparable to findings in previous studies after adjustment for inflation.[11, 36] It should be noted that the present study found that racial/ethnic minority groups had lower family expenditures and insurance-paid expenditures compared to White/other races. These lower expenditures may merely reflect minority groups having significantly lower levels of medical care seeking behaviors. In addition, a higher proportion of Hispanic children and Black or African American children, compared to Whites/other races, have public insurance coverage, which usually pays significantly less than private insurance for the same medical service, and usually does not require families to pay out-of-pocket for care. Finally, it should also be noted that even though the families of Black children might be spending less out-of-pocket for medical expenditures, such expenses may still pose a higher relative financial burden on these families, especially considering the fact that Black children were most likely to be from families in the lowest income quantile. Similarly, Hispanic children were also most likely to be from families in the lowest income quantile. This suggests that these families, who had non-significantly different TBI-related expenditures compared to White families, may bear a particularly high financial burden related to pediatric TBI, perhaps partly because Hispanic children are also more likely than non-Hispanic children to be uninsured. Unfortunately, financial burden could not be examined precisely using the current MEPS datasets. Because the family income variable in MEPS was coded as a categorical rather than continuous variable, we were unable to compute the exact out-of-pocket expense to household income ratio. Future research with more information regarding medical expenditure/income ratios will be able to shed light on this important issue.

### Study limitations

The present study has several limitations. First, although missing values in the MEPS variables are rare because of quality control and imputation methods implemented by the AHRQ, the variables used in the present study had, on average, approximately 2% missingness rates. When the percentage of missing data points is less than 5%, different approaches for handling the missing data tend to yield similar results. Therefore, the present study used pairwise deletion. Second, as described in the methodology section, the present study only used the publically available three-digit ICD-9 codes to identify TBIs, instead of the full five-digit ICD-9 codes, due to the insufficient information provided by the five-digit ICD-9 codes to compute head AIS scores as a valid measure of TBI severity to categorize pediatric TBI cases into statistically-valid subgroups for analysis. Third, due to the nature of MEPS as a population-based database, there was a relatively small sample size of pediatric TBI cases in the present study. It is possible that individuals with better access to healthcare services might be overpresented while those with poor access to care were underreported. Fourth, also related to the limited sample size, although the conventional rule-of-thumb suggested the sample size is sufficient to avoid overfitting the regression models, it is reasonable to deduce that a larger sample might be able to provide greater statistical power to detect effect sizes of those socio-demographic factors (e.g., insurance status) that were non-significant in the present study. Finally, although the present study incorporated multivariable log-linear regression analyses, the findings are primarily hypothesis generating as we could not ascertain the underlying mechanisms driving the differences in reported pediatric TBI incidence, medical care seeking behaviors, and medical expenditures among sociodemographic groups. Therefore, future research is needed to investigate underlying cause(s) of the healthcare disparities in healthcare service utilization and expenditures identified in the present study.

## Conclusions

The present study analyzed the Medical Expenditure Panel Survey data, a population-based survey, to examine pediatric TBI incidence and associated medical care seeking behaviors and medical expenditures in the United States over 12 years. This study is among the first to compare various TBI-related medical expenditures (based on the source of payment and medical service provided) among different sociodemographic groups within the U.S. pediatric population. The findings of this research on economic burdens and disparities in healthcare service utilization for pediatric TBI take on special significance in view of the dramatic increase in these injuries over the past decade and support the need for further eduation and policy-making to improve access to healthcare services among racial/ethnic minorities.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgements

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**Table 1 –**

Overview of sample sizes and national estimates of children with traumatic brain injuries (TBI), pediatric TBI cases, and medical expenditures, MEPS[a] 2004−2015.

| | Sample Size | National Estimate[b] | 95% CI |
|---|---|---|---|
| Total population | 178,850 | 312,290,459 | (303,166,881−321,414,036) |
| Number of children | 50,563 | 74,304,545 | (71,542,362−77,066,729) |
| Number of children with TBI | 449 | 452,011 | (393,009−511,014) |
| Number of pediatric TBIs | 451 | 453,220 | (393,772−512,666) |
| Number of TBIs had medical treatment(s) | 369 | 384,125 | (328,113−440,137) |
| Number of patients had emergency room visit | 256 | 250,384 | (210,265−290,503) |
| Number of patients hospitalized | 21 | 15,283.00 | (6,556−24,009) |
| Total expenditures per year ($) | | 666,741,567 | (402,504,729−1,085,122,334) |
| Median expenditures per TBI, IQR ($) | | 383 | (80−918) |
| Mean expenditures per TBI ($) | | 1,532 | (736−2,329) |

[a]MEPS: Medical Expenditure Panel Survey.

[b]Calculated as annual average during 2004−2015.

**Table 2 –**

National estimates of pediatric traumatic brain injuries (TBI) by socio-demographic factors MEPS[a] (2004−2015).

| | | Sample Size | National Estimate[b] | % Incidence of TBI | 95% CI for Incidence of TBI | Predictors of TBI OR[c] | 95% CI for Predictors of TBI |
|---|---|---|---|---|---|---|---|
| Total | | 451 | 453,220 | 1.22 | (1.07−1.37) | | |
| Age | 0−4 yrs | 106 | 91,964 | 0.90 | (0.66−1.13) | | |
| | 5−9 yrs | 92 | 81,280 | 0.80 | (0.56−1.04) | 0.78 | (0.53−1.15) |
| | 10−14 yrs | 135 | 153,948 | 1.50 | (1.19−1.82) | 1.47 | (1.02−2.11) |
| | 15−17 yrs | 118 | 126,028 | 1.93 | (1.46−2.40) | 1.85 | (1.30−2.63) |
| Sex | Male | 309 | 313,404 | 1.65 | (1.43−1.87) | | |
| | Female | 142 | 139,815 | 0.77 | (0.60−0.94) | 0.47 | (0.36−0.60) |
| Race/ Ethnicity | White/Other Race | 266 | 343,093 | 1.56 | (1.32−1.80) | | |
| | Black | 68 | 41,908 | 0.80 | (0.55−1.05) | 0.58 | (0.39−0.85) |
| | Hispanic | 100 | 56,179 | 0.67 | (0.53−0.82) | 0.56 | (0.41−0.77) |
| | Asian | 17 | 12,039 | 0.75 | (0.32−1.18) | 0.51 | (0.27−0.93) |
| Pre-Injury Disability | Without disability | 415 | 421,455 | 1.18 | (1.04−1.33) | | |
| | With disability | 36 | 31,764 | 2.01 | (1.18−2.85) | 1.51 | (0.97−2.36) |
| Family Income Level | High income (≥400% FPL[d]) | 120 | 180,335 | 1.93 | (1.54−2.31) | | |
| | Middle income (200−399% FPL) | 134 | 127,734 | 1.11 | (0.87−1.36) | 0.62 | (0.45−0.86) |
| | Low income (< 200% FPL) | 197 | 145,150 | 0.89 | (0.72−1.06) | 0.61 | (0.44−0.85) |
| Health Insurance | Any private | 269 | 321,565 | 1.46 | (1.25−1.67) | | |
| | Public only | 166 | 116,123 | 0.90 | (0.72−1.09) | 0.99 | (0.72−1.35) |
| | Uninsured | 16 | 15,531 | 0.68 | (0.28−1.09) | 0.53 | (0.29−0.99) |
| Parental Education | Less than high school | 52 | 27,329 | 0.65 | (0.41−0.90) | | |
| | High school | 108 | 96,846 | 1.17 | (0.84−1.49) | 1.40 | (0.87−2.24) |
| | College and higher | 279 | 318,682 | 1.44 | (1.26−1.63) | 1.39 | (0.90−2.14) |
| Parental Marriage Status | Both parents | 285 | 323,430 | 1.35 | (1.17−1.54) | | |
| | Single parents | 140 | 103,644 | 1.11 | (0.86−1.36) | 1.14 | (0.85−1.54) |

| | Sample Size | National Estimate[b] | % Incidence of TBI | 95% CI for Incidence of TBI | Predictors of TBI OR[c] | 95% CI for Predictors of TBI |
|---|---|---|---|---|---|---|
| No parents | 26 | 26,146 | 0.67 | (0.29−1.05) | 0.80 | (0.34−1.87) |

[a]MEPS: Medical Expenditure Panel Survey

[b]Calculated as annual average during 2004−2015

[c]OR: Odds Ratio

[d]FPL: Federal Poverty Line

**Table 3 –**

Medical seeking behavior and medical expenditures by socio-demographic factors among pediatric traumatic brain injuries (TBI), MEPS[a] 2004−2015.

| | | % Medical Seeking Behavior (Percent of "Yes") | 95% CI for Medical Seeking Behavior (Percent of "Yes") | Total expenditure ($) - Median Per TBI | Total expenditure ($) - IQR[b] | Family expenditure ($) - Median Per TBI | Family expenditure ($) - IQR | Societal expenditure ($) - Median Per TBI | Societal expenditure ($) - IQR |
|---|---|---|---|---|---|---|---|---|---|
| Age | 0−4 yrs | 84.09 | (75.01−93.17) | 369 | (108−876) | 0 | (0−32) | 313 | (70−649) |
| | 5−9 yrs | 89.88 | (84.38−95.38) | 413 | (67−898) | 22 | (0−81) | 273 | (37−691) |
| | 10−14 yrs | 82.49 | (75.52−89.46) | 320 | (69−930) | 0 | (0−43) | 263 | (53−681) |
| | 15−17 yrs | 84.70 | (76.96−92.44) | 442 | (88−916) | 21 | (0−133) | 243 | (11−916) |
| Sex | Male | 83.75 | (78.91−88.59) | 370 | (66−917) | 0 | (0−74) | 272 | (35−857) |
| | Female | 87.00 | (81.12−92.88) | 434 | (127−901) | 6 | (0−72) | 305 | (90−699) |
| Race/ Ethnicity | White/Other Race | 87.10 | (82.38−91.82) | 426 | (105−959) | 12 | (0−85) | 342 | (56−871) |
| | Black | 69.07 | (55.17−82.96) | 183 | (0−440) | 0 | (0−0) | 134 | (0−336) |
| | Hispanic | 80.20 | (71.51−88.89) | 318 | (40−926) | 0 | (0−40) | 220 | (0−619) |
| | Asian | 93.82 | (84.47−100.00) | 341 | (77−1,288) | 16 | (0−28) | 324 | (52−1,174) |
| Pre-Injury Disability | Without disability | 84.19 | (79.91−88.47) | 383 | (73−919) | 0 | (0−81) | 293 | (38−781) |
| | With disability | 92.25 | (84.67−99.83) | 370 | (170−701) | 12 | (0−50) | 370 | (140−624) |
| Family Income Level | High income (≥400% | 85.74 | (78.47−93.01) | 474 | (107−977) | 41 | (0−140) | 338 | (56−696) |
| | Middle income (200−399% FPL[c]) | 77.83 | (69.90−85.77) | 195 | (27−841) | 11 | (0−54) | 122 | (0−651) |
| | Low income (<200% FPL) | 86.82 | (80.84−92.79) | 402 | (165−921) | 0 | (0−3) | 336 | (79−786) |
| Health Insurance | Any private | 84.58 | (79.57−89.59) | 432 | (70−993) | 27 | (0−130) | 315 | (37−915) |
| | Public only | 88.85 | (83.32−94.38) | 302 | (111−694) | 0 | (0−0) | 298 | (96−626) |
| | Uninsured | 57.80 | (27.97−87.63) | 88 | (0−484) | 0 | (0−17) | 0 | (0−322) |
| Parental Education | Less than high school | 82.96 | (72.56−93.37) | 273 | (44−911) | 0 | (0−0) | 254 | (44−888) |
| | High school | 91.64 | (85.83−97.44) | 474 | (171−1,173) | 0 | (0−32) | 422 | (115−919) |

| | | % Medical Seeking Behavior (Percent of "Yes") | 95% CI for Medical Seeking Behavior (Percent of "Yes") | Total expenditure ($) - Median Per TBI | Total expenditure ($) - IQR[b] | Family expenditure ($) - Median Per TBI | Family expenditure ($) - IQR | Societal expenditure ($) - Median Per TBI | Societal expenditure ($) - IQR |
|---|---|---|---|---|---|---|---|---|---|
| | College and higher | 83.35 | (78.24−88.45) | 371 | (70−891) | 19 | (0−114) | 273 | (25−651) |
| Parental Marriage Status | Both parents | 85.44 | (80.57−90.31) | 459 | (101−981) | 19 | (0−110) | 335 | (53−866) |
| | Single parents | 86.19 | (77.27−95.11) | 305 | (56−808) | 0 | (0−6) | 247 | (32−593) |
| | No parents | 80.26 | (67.90−92.63) | 167 | (71−500) | 0 | (0−26) | 124 | (71−500) |

[a] MEPS: Medical Expenditure Panel Survey

[b] IQR: interquartile range

[c] FPL: Federal Poverty Line

**Table 4 –**

Logistic regression models on TBI, seeking medical treatment, and loglinear regression model on expenditures for pediatric traumatic brain injuries, MEPS[a] 2004−2015.

| | | Medical Seeking Behavior OR[b] | 95% CI for Medical Seeking Behavior | Ratio (total expenditure) | 95% CI | Ratio (family expenditure) | 95% CI | Ratio (societal expenditure) | 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| Age | 0−4 yrs | | | | | | | | |
| | 5−9 yrs | 1.81 | (0.66−5.00) | 1.14 | 0.50−2.62 | 2.06 | 0.89−4.78 | 1.00 | 0.40−2.46 |
| | 10−14 yrs | 0.72 | (0.26−2.00) | 0.76 | 0.34−1.70 | 0.93 | 0.45−1.91 | 0.77 | 0.33−1.78 |
| | 15−17 yrs | 0.90 | (0.35−2.27) | 0.96 | 0.48−1.94 | 1.96 | 0.97−3.94 | 0.68 | 0.30−1.56 |
| Sex | Male | | | | | | | | |
| | Female | 1.12 | (0.61−2.08) | 1.20 | 0.71−2.02 | 1.44 | 0.85−2.41 | 1.14 | 0.63−2.07 |
| Race/ Ethnicity | White/Other Race | | | | | | | | |
| | Black | 0.29 | (0.12−0.69) | 0.22 | 0.08−0.59 | 0.35 | 0.18−0.67 | 0.27 | 0.10−0.77 |
| | Hispanic | 0.47 | (0.20−1.10) | 0.57 | 0.25−1.28 | 1.04 | 0.49−2.22 | 0.41 | 0.17−1.00 |
| | Asian | 2.25 | (0.40−12.60) | 1.67 | 0.54−5.13 | 0.60 | 0.19−1.84 | 1.70 | 0.45−6.40 |
| Pre-Injury Disability | Without disability | | | | | | | | |
| | With disability | 2.15 | (0.60−7.75) | 1.64 | 0.78−3.45 | 1.33 | 0.65−2.70 | 2.25 | 1.01−5.02 |
| Family Income Level | High income (≥400% FPL[c]) | | | | | | | | |
| | Middle income (200−399% FPL) | 0.58 | (0.26−1.34) | 0.49 | 0.23−1.06 | 0.57 | 0.30−1.07 | 0.49 | 0.21−1.13 |
| | Low income (< 200% FPL) | 1.53 | (0.47−5.00) | 1.36 | 0.53−3.53 | 0.64 | 0.29−1.42 | 0.97 | 0.33−2.82 |
| Health Insurance Any private | | | | | | | | | |
| | Public only | 1.00 | (0.32−3.14) | 0.67 | 0.29−1.57 | 0.12 | 0.07−0.22 | 0.90 | 0.35−2.30 |
| | Uninsured | 0.33 | (0.07−1.50) | 0.38 | 0.05−2.72 | 0.92 | 0.19−4.34 | 0.20 | 0.03−1.58 |
| Parental Education | Less than high school | | | | | | | | |
| | High school | 2.27 | (0.63−8.19) | 1.81 | 0.64−5.11 | 0.80 | 0.38−1.69 | 1.36 | 0.45−4.06 |
| | College and higher | 1.09 | (0.38−3.11) | 0.94 | 0.33−2.69 | 0.90 | 0.44−1.83 | 0.58 | 0.20−1.72 |

| | | Medical Seeking Behavior OR[b] | 95% CI for Medical Seeking Behavior | Ratio (total expenditure) | 95% CI | Ratio (family expenditure) | 95% CI | Ratio (societal expenditure) | 95% CI |
|---|---|---|---|---|---|---|---|---|---|
| Parental Marriage Status | Both parents | | | | | | | | |
| | Single parents | 0.96 | (0.40−2.30) | 0.82 | 0.39−1.73 | 0.37 | 0.19−0.72 | 1.27 | 0.58−2.79 |
| | No parents | 0.95 | (0.24−3.79) | 0.88 | 0.23−3.35 | 1.23 | 0.57−2.63 | 1.26 | 0.29−5.49 |

[a]MEPS: Medical Expenditure Panel Survey

[b]OR: Odds Ratio

[c]FPL: Federal Poverty Line

**Table 5 –**

Distribution of health care expenditures for pediatric traumatic brain injuries, by type of service and by payment source, MEPS 2004−2015.

| | National estimate of total expenditures $[a] | Percent (%) | 95% CI[b] |
|---|---|---|---|
| Total expenditure | 666,741,567 | 100 | (402,504,729−1,085,122,334) |
| By type of service | | | |
| Ambulatory | 91,935,264 | 13.8 | (70,436,797−115,650,736) |
| Emergency department | 244,730,552 | 36.7 | (193,046,761−303,147,728) |
| Hospital inpatient | 319,179,862 | 47.9 | (81,636,723−678,936,102) |
| Home health | 5,777,814 | 0.8 | *c* |
| Prescribed medicines | 5,118,074 | 0.8 | (2,353,906−8,313,356) |
| By source of payment | | | |
| Private insurance | 472,757,764 | 70.9 | (223,468,220−833,251,952) |
| Family (out of pocket) | 55,212,972 | 8.3 | (39,521,730−75,692,804) |
| Medicare | 1,053,975 | 0.2 | *c* |
| Medicaid | 82,505,576 | 12.4 | (54,253,508−117,592,368) |
| Other[d] | 55,211,280 | 8.2 | (32,450,745−82,015,938) |

[a] All expenditures were adjusted for inflation and converted to constant 2015 dollars using the Personal Health Care Expenditure (PHCE) index for overall health care.

[b] Calculated using bootstrap methods (the number of repeating bootstrap samples is 2000)

[c] Not presented because the estimation was based on small number of patients ($n < 10$)

[d] Other sources include payments from the Department of Veterans Affairs (except TRICARE); other Federal sources (Indian Health Service, military treatment facilities, and other care provided by the Federal Government); various State and local sources (community and neighborhood clinics, State and local health departments, and State programs other than Medicaid); various unclassified sources (e.g., automobile, homeowner’s, or other liability insurance, and other miscellaneous or unknown sources); Medicaid payments reported for persons who were not reported as enrolled in the Medicaid program at any time during the year; work’s compensation, and private insurance payments reported for persons without any reported private health insurance coverage during the year.