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The impact of traumatic brain injury on economic productivity in the Caribbean

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ABSTRACT

Introduction: Traumatic brain injury (TBI) is a significant cause of morbidity and mortality in the Caribbean as well as globally. Within the Caribbean, the prevalence of TBI is approximately 706 per 100,000 persons – one of the highest rates per capita in the world.
Research question: We aim to assess the economic productivity lost due to moderate to severe TBI in the Caribbean.
Material and methods: The annual cost of economic productivity lost in the Caribbean from TBI was calculated from four variables: (1) the number of people with moderate to severe TBI of working age (15–64 years), (2) the employment-to-population ratio, (3) the relative reduction in employment for people with TBI, and (4) per capita Gross Domestic Product (GDP). Sensitivity analyses were performed to evaluate whether the uncertainty of the TBI prevalence data result in substantive changes in the productivity losses.
Results: Globally, there was an estimated 55 million (95% UI 53, 400, 547 to 57, 626, 214) cases of TBI in 2016 of which 322,291 (95% UI 292,210 to 359,914) were in the Caribbean. Using GDP per capita, we calculated the annual cost of potential productivity losses for the Caribbean to be $1.2 billion.
Discussion and conclusion: TBI has a significant impact on economic productivity in the Caribbean. With upwards of $1.2 billion lost in economic productivity from TBI, there is an urgent need for appropriate prevention and management of this disease by upscaling neurosurgical capacity. Neurosurgical and policy interventions are necessary to ensure the success of these patients in order to maximize economic productivity.

1. Introduction

Traumatic brain injury (TBI) is a significant cause of morbidity and mortality in the Caribbean as well as globally. TBI is defined as an alteration in brain function or other evidence of brain pathology caused by an external force with data suggesting the majority of TBI cases (60%) are a result of road traffic accidents, followed by falls (20–30%), and violence (10%) (Menon et al., 2010; Gururaj, 2002). The global prevalence of TBI is 55 million while the age-standardized prevalence rate is 759 (95% UI 731 to 788) per 100,000 population, representing an increase of 8.4% (95% UI 7.7 to 9.2) between 1990 and 2016 (James, 2019). The annual incidence of TBI affects is over 10 million globally, leading to either mortality or hospitalization (Hydera et al., 2007).

Importantly, unmanaged, or under-managed TBI frequently leads to serious neurological sequelae such as post-traumatic epilepsy, motor impairment or cognitive decline, all of which can compromise an individual's ability to work (Cuthbert et al., 2015; Howe et al., 2018). The resultant cognitive deficits, mood disorders, sleep disturbances, chronic pain, weakness or plegia caused by TBI can lead to long-term effects which frequently impair the ability to work (Cuthbert et al., 2015; Howe

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et al., 2018). Previous studies demonstrate the impact of TBI on employment: the linear trajectory of employment probabilities for the sample cohort evaluated remained at ~50% across 1, 2, 5, and 10-years post-injury (Howe et al., 2018). The prevalence of unemployment in the United States after traumatic brain injury for working age individuals was investigated and about 6 in 10 of working age adults with TBI (60.4%, 38,682 people) were found to be unemployed at 2 years post-injury (Cuthbert et al., 2015). Graff et al. highlighted that 43% of patients were not attending ordinary work 5 years after diagnosis (Graff et al., 2019). Moreover, odds of impaired attachment to labor markets increasing from 6 months (OR 1.30, 95%CI 1.24 to 1.36) to 5 years (OR 1.54, 95%CI 1.45 to 1.63) following TBI diagnosis (Graff et al., 2019).

Within the Caribbean, a region of the Americans with over 30 island states and dependencies, the prevalence of TBI is approximately 706 per 100,000 persons, which is one of the highest rates per capita in the world (James, 2019). TBI exerts significant financial strain on national economies and health systems in the Caribbean, from its significant costs to national healthcare systems, to its costs to families in terms of loss of DALYs and income (Asmamaw et al., 2019; Corso et al., 2006; Dunnel et al., 2020; Fu et al., 2016; Hoang et al., 2008; Humphreys et al., 2013; Olesena et al., 2012; Marques et al., 2021; Rolle et al., 2022; Taylor et al., 2017; Te Ao, 2014; Tuomine et al., 2012). The financial burden is often in the form of lost productivity as most victims of TBI are relatively young and in their productive years (Humphreys et al., 2013). The lost wages and savings have both microeconomic impacts at the household level as well as macroeconomic impacts at the community or national levels (Asmamaw et al., 2019; Corso et al., 2006; Dunnel et al., 2020; Fu et al., 2016; Hoang et al., 2008; Humphreys et al., 2013; Olesena et al., 2012; Marques et al., 2021; Rolle et al., 2022; Taylor et al., 2017; Te Ao, 2014; Tuomine et al., 2012).

In this study we aim to assess the extent of economic productivity loss due to moderate to severe TBI in the Caribbean. While mild TBI does not lead to severe disability, both moderate or severe injury can cause severe morbidity impacting activities of daily living and livelihood (Dunnel et al., 2020). The study also seeks to highlight TBI management, and the investments needed to curb the productivity implications of this disease – especially in resource limited settings.

2. Methods

Using the approach by Marques et al. (2021) we calculate the annual cost of economic productivity lost in the Caribbean from TBI from four different types of data (Marques et al., 2021): (1) the number of people with moderate to severe TBI of working age (15–64 years), (2) the employment-to-population ratio, (3) the relative reduction in employment for people with TBI, and (4) per capita Gross Domestic Product (GDP). These figures were obtained from the World Bank's Development Indicators for the year 2016. The World Bank Development indicators are collected for most countries in the Caribbean and usually come from national surveys that are comparable across countries.

2.1. Estimating the annual cost of economic productivity loss

The annual potential productivity loss associated with reduced employment was estimated for the Caribbean using the formula: Annual potential productivity losses = TBI in the working age population X Employment to population ratio X Relative Reduction in employment X GDP per capita.

The variables have been defined as follows.

i. Prevalence of TBI in the working age population

Precise data on prevalence of TBI in people of working age in the Caribbean is not directly available in studies. We estimated the number of individuals impacted by first establishing the number of individuals globally people with TBI from the 2016 Global Burden of Disease (GBD) study, which applies TBI age-standardized prevalence rates (James, 2019). The working age population was defined as those aged 15–64 years old, as prior studies have demonstrated TBI tends to affect those in the working age population disproportionately more than those in other age groups, although the proportions may differ between studies (Asmamaw et al., 2019; Fu et al., 2016; Hoang et al., 2008). Only one study among those reviewed conducted by Fu et al. provided a specific estimation of approximately 60% (Fu et al., 2016). This ratio was adopted and multiplied by the 2016 TBI prevalence rate in the Caribbean to estimate the number of TBI cases in the working age population.

ii. Employment-to-population ratio

Employment to population ratio is the proportion of a country's population that is employed. Employment is defined as persons of working age who, during a short reference period, were engaged in any activity to produce goods or provide services for pay or profit, whether at work during the reference period (i.e., who worked in a job for at least 1 h) or not at work due to temporary absence from a job, or to working-time arrangements. Ages 15 and older are generally considered the working-age population. We sourced this data from the World Bank's World Development Indicator database for 2016.

iii. Relative reduction in employment for people with TBI

We estimated the relative reduction in employment for TBI in the Caribbean by drawing on Howe et al. and Cuthbert et al. who cited data from other countries that demonstrated a 60% reduction in employment for people impacted by TBI (Cuthbert et al., 2015; Howe et al., 2018). Our current study used these estimates and established the relative reduction in employment for people with TBI in the Caribbean at 60%.

iv. Gross domestic product (GDP) per capita

GDP per capita is gross domestic product divided by midyear population, whereas GDP in itself is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Data were sourced from the World Bank's World Development Indicator database in 2016 US Dollars. Applying the methodology used by Marques et al. for productivity losses resulting from blindness, we defined the annual cost of potential productivity losses associated with reduced employment due to TBI equal to GDP per capita (Marques et al., 2021).

Sensitivity analyses were performed to evaluate whether the uncertainty of the TBI prevalence data and the relative reduction in employment data result in substantive changes in the productivity losses.

3. Results

There were an estimated 55 million (95%UI (53, 400, 547 to 57, 626, 214)) cases of TBI in 2016 globally, of which 322,291 (95%UI 292,210 to 359,914) were in the Caribbean (James, 2019). Table 1 shows TBI incidence and prevalence rates with the corresponding age-standardized rates for selected regions of the world as defined by the WHO in the 2016 Global Burden of Disease analysis (James, 2019). The Caribbean has one of the highest TBI age-standardized incidence and prevalence rates globally.

Using GDP per capita, we calculated the annual cost of potential productivity losses for the Caribbean to be $1.2 billion. This overall productivity loss amount represents 0.3% of the region's GDP in 2016. Sensitivity analyses demonstrated substantive changes in the productivity losses. Table 2 shows the productivity losses when we vary TBI prevalence using the upper and lower limit of the confidence interval while holding other variables constant. The lower and upper limit of the prevalence data yield productivity losses of $1 billion and $1.3 billion respectively. Wide variations are observed when the relative reduction in

Table 1
Prevalence and incidence of traumatic brain injuries in the caribbean and selected regional blocks, 2016

Region	Incidence Rate	Age-Standardized Incidence Rate	Prevalence Rate	Age-Standardized Prevalence Rate
Caribbean	145,899	320	322,291	706
Central Latin America	716,600	293	1,412,146	609
Asia Pacific	563,538	276	1,256,353	489
Western Europe	1,262,700	292	3,021,435	546
North America	1,221,494	329	2,603,351	600
East Asia	4,481,454	312	12,301,082	739
Sub-Saharan Africa	2,956,908	326	4,182,169	621
Southeast Asia	1,843,182	283	4,070,463	649
Oceania	31,414	282	52,480	565
Southern Latin America	148,473	225	270,239	392

Source: Global Burden of Disease Report (2016

Table 2
Sensitivity analysis of productivity losses with variations in TBI prevalence.

Variables	Lower limit	Middle	Upper limit
TBI in working age population[a]	175,327	193,347	215,948
Employment to population ratio	55%	55%	55%
Relative reduction in employment	60%	60%	60%
GDP per capita	$18,143	$18,143	$18,143
Productivity losses	$1,049,716,061.13	$1,157,605,224.93	$1,292,921,706.12

[a] TBI in working age population has been varied while other variables remain constant for lower, middle and upper limit.

employment is varied using 25% and 75% for lower and upper limits respectively while holding other variables constant (Table 3). The lower limit yields productivity losses of $482 million. The upper limit yields productivity losses of $1.4 billion.

4. Discussion

We report the first calculation in the literature of economic productivity loss due to TBI in the Caribbean to be $1.2 billion annually (0.3% of the region's GDP) using economic data from the World Bank Development Indicators. For developing and developed nations, such as those in the Caribbean, economic productivity is inextricably linked to the health of the population (Asmamaw et al., 2019; Corso et al., 2006; Fu et al., 2016; Hoang et al., 2008; Humphreys et al., 2013; Olesena et al., 2012; Marques et al., 2021; Te Ao, 2014; Tuomine et al., 2012; Ezoji et al., 2019). Unmanaged or under-managed TBI in the Caribbean leads to serious neurological sequelae such as post-traumatic epilepsy, physical impairment or cognitive decline, which can compromise an individual's ability to work, and drives productivity loss through the following: (1) absence from work (absenteeism), (2) reduction in production while at work (presenteeism), or (3) reduction in employment (job loss and early retirement) (Asmamaw et al., 2019; Theadom et al., 2017; Silverberg et al., 2018). Early retirement has been shown to demonstrate a significant productivity loss in severe TBI patients, calculated as $1.16 million per year in a population studied in Finland (Tuomine et al., 2012). For many individuals in the Caribbean, their primary asset is their ability to work and participate in the labor force, and as such, these effects are likely to demonstrate a relatively larger impact on their society. Therein, brain injury from trauma has significant microeconomic and macroeconomic implications for the region.

Understanding the burden of disease from TBI and its economic sequalae suggests that there are meaningful opportunities for intervention and improvement to address these impacts. Whether TBI in one island is a function of boating accidents or motor vehicle accidents, understanding the specific causes of TBI per population allows policymakers to better address those causes within that demographic. Systemic gaps in equitable and accessible neurosurgical care pose significant public health challenges for providers and major stakeholders. Approximately 3.5 million Caribbean citizens live outside of the timely-access zone for urgent or emergent neurosurgical care, with approximately 1 neurosurgeon for every 380,000 persons (Rolle et al., 2021). To date, there is no comprehensive neurosurgical registry or database to track pathologies and several of the low-income Caribbean countries have poor preventative governance around road traffic safety (Rolle et al., 2022). Caribbean economies are largely supported by human capital and labor; therefore, improved management of TBI through addressing health domains that bridge gaps in care may advance economic productivity.

Building neurosurgical capacity in the Caribbean to manage TBI will need to start with investments in workforce, policy changes in infrastructure, service delivery efforts, information management, and governance initiatives. In addition to infrastructure and human resource investments – such as operating theatre space, training and retaining neurosurgeons, developing research capacity, equipping neurosurgeons with updated technology and instrumentation, and improving system communications – policy changes and prevention will be essential. Prioritizing the prevention of surgical disease is both cost-effective and salient. Prevention is driven primarily by emphasizing effective policies, rigorous data collection, and research, all of which drive and further inform policy, as highlighted by the Lancet Commission on Global Surgery's (LCoGS) national surgical, obstetric, and anesthesia plans (NSOAP) (Meara et al., 2015). Of the many examples of prevention that may serve to curtail the burden of TBI, public policy regarding traffic regulation and helmet use may be of significant benefit to decreasing the impact of motor vehicle accidents on the overall health of the populace, and especially in decreasing the impact of traumatic brain injury (Rolle et al., 2022).

Scaling up direct delivery of neurosurgical care is intensive. It requires investment in diagnostic imaging modalities, in addition to clinical management development that targets infrastructure, human resources, peri- and post-operative capacity, and rehabilitation (Daniels et al., 2020; Bath et al., 2019; Bowen et al., 2012; Fleming et al., 2021; Kayani et al., 2009; Maas and Menon, 2017; Stocchetti and Zanier, 2016). Development of a competent and skilled workforce at every level of care,

Table 3
Sensitivity analysis of productivity losses with variations in relative reduction in employment.

Variables	Lower limit	Middle	Upper limit
TBI in working age population	193,347	193,347	193,347
Employment to population ratio	55%	55%	55%
Relative reduction in employment[a]	25%	60%	75%
GDP per capita	$18,143	$18,143	$18,143
Productivity losses	$482,335,510.39	$1,157,605,224.93	$1,447,006,531.16

[a] Relative reduction in employment has been varied while other variables remain constant for lower, middle and upper limit.

whilst emphasizing excellent training programs and the retention of a highly skilled workforce will be essential, especially in regions like the Caribbean (Daniels et al., 2020). Additionally, information management system development cannot be overstated, as the ability to accurately record and follow the epidemiology of disease will ensure that patients are not lost to follow-up and that providers can ensure that the standard of care is being provided to all patients (Bath et al., 2019). While the scope and scale of these investments may be viewed as limiting, these costs are a fraction of the annual estimated cost of TBI in the region and the opportunity cost of continual loss of economic productivity from TBI may quickly outweigh the cost of these investments. Although cost estimates for infrastructure development in the Caribbean will vary based on the health domains that countries choose to target, the precedents of investing in healthcare infrastructure development to promote better clinical outcomes and decrease costs associated with neurological conditions are well documented in the literature (Bowen et al., 2012). In an analysis of the relative economic utility of developing epilepsy surgery infrastructure in lieu of continued medical management of refractory epilepsy patients in Ontario, Canada, Bowen et al. demonstrated an incremental cost-effectiveness ratio of 0.36 per quality-adjusted life year (QALY) when comparing epilepsy surgery with continued medical management, further highlighting the utility of investing in initiatives that improve clinical outcomes and decrease costs (Bowen et al., 2012). By pivoting the approach of managing neurosurgical diseases towards public health and equity, Caribbean countries keep viable members of the workforce healthy and potentially save $1.2 billion per year to use for nation-building in all sectors of health domains and development.

5. Strengths

The strengths of our study include the development and use of a relatively simple formula to estimate potential productivity losses that can be easily replicated in other regions to evaluate the case for investing in interventions to upscale prevention efforts and neurosurgical care for TBI patients. Our estimates were based on the latest available data and used GDP per capita and employment to population ratio which are relatively available in many settings. These publicly available data are updated annually and are internationally standardized, which increases the reliability of our estimates. We based our estimates of the relative reduction in employment due to TBI and the number of TBI in the working age population on a literature review, which is relatively easier than if these had to be determined another way.

6. Limitations

Our analysis has several limitations. First, there are relatively few preceding reports on which to base our estimates of the relative reduction in employment associated with TBI. Furthermore, none of these estimates were from the Caribbean. This consequently affects how we measure productivity loss, as the accuracy and reliability of these estimates heavily impacts our final results. Moreover, although TBI prevalence data was available for several Caribbean countries, we analyzed at a regional rather than country level to account for the variable data at a country level. This does not allow us to account for the heterogeneity in socioeconomic factors and variations in GDP per capita between the Caribbean countries. As incidence of TBI differ between countries in the region there could be significant overestimations of the economic productivity loss in some countries and overestimations in others. The use of national rather than regional data would address these limitations.

We performed a sensitivity analysis to study the impact of changes in the relative reduction in employment. The studies from which the estimates for this variable were obtained are few and may not be generalizable for a large region such as the Caribbean. To derive the best estimate, assumptions were necessary, which can introduce uncertainty at this stage. Additionally, the impact from relative reduction in employment may differ globally depending on the existing social welfare systems. This information was not available for the region.

There are several productivity loss components that we did not include in our estimates, such as those resulting from premature mortality, absenteeism and presenteeism (reduced productivity in the workplace) and productivity losses of caregivers. We also recognize that we have not included the productivity losses related to unpaid or informal labor activities. Our reason for not including these additional components is purely due to a lack of data, especially for the Caribbean region. It is true that excluding these elements is likely to have resulted in an underestimate of the overall magnitude of productivity losses due to TBI.

Due to the limitations of available data, our estimations do not factor levels of severity of TBI which is known to impact productivity costs leading to a limitation in this study. Similarly, the paper does not account for the productivity losses from mild TBI. The reason is that while mild TBI has also been shown to impair working ability, the bigger impact tends to be from moderate to severe TBI. We believe future studies can build on our foundational work to further advance this area of research.

7. Conclusions

TBI has a significant impact on the economic productivity in the Caribbean. With estimates potentially upwards of $1.2 billion lost in economic productivity from TBI, the appropriate prevention and management of this neurosurgical disease by upscaling neurosurgical capacity highlights the importance of this initiative for not only health outcomes but also national economic metrics. This means that neurosurgeons and policy makers, from the Caribbean and other resource limited settings, have an active role to play in the reduction of morbidity and mortality in TBI patients, which will lead to improvement in the economic statuses of countries who prioritize these interventions.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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