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MORTALITY FROM EXTERNAL CAUSES AND BEHAVIORAL MECHANISMS

An examination of data from low- and middle-income countries

Anne Abio

TURUN YLIOPISTON JULKAISUJA – ANNALES UNIVERSITATIS TURKUENSIS
SARJA – SER. D OSA – TOM. 1728 | MEDICA – ODONTOLOGICA | TURKU 2023

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To my beloved family, parents,
brothers and sisters

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ABSTRACT

External causes of mortality are among the leading causes of mortality, especially in low- and middle-income countries. External causes of mortality disproportionately affect youth and young adults, including those who are economically active. The aim of the following study series was to investigate trends and demographic associations of the injury-related mortality burden and suicidal behavior in low- and middle-income countries.

Study I examined trends of external causes of mortality in Seychelles over a period of 30 years using civil registration data. At least three-quarters of injury deaths occurred among males. The leading causes of mortality among males was drowning, followed by road traffic injuries; and other unintentional injuries among females. The injury mortality declined over time; however, the injuries from road traffic crashes increased, especially among males.

Study II analyzed trends of traumatic brain injury (TBI) related mortality in Seychelles over a span of 30 years using civil registration data. Males were more likely to die from TBI related injuries. TBIs contributed to one in five deaths from all the recorded external causes. Road traffic crashes were the leading mechanism of TBI related mortality.

Study III estimated the prevalence of suicidal behavior and the associated contextual factors among adolescents in low- and middle-income countries using the Global School-based Student Health Survey data. Ten to eleven percent of adolescents had considered suicide, made a suicide plan, or attempted suicide in each case. The lowest prevalence was reported in the South East Asian region, while a higher prevalence was recorded in the low-income country regions of the Americas.

The findings imply that effective policies tailored for low- and middle-income countries are required to reduce the high rates of injury mortality. Reducing injury mortality will contribute towards each respective economy by minimizing the losses of income faced by the economically active age groups, which will in turn be beneficial for the countries.

KEYWORDS: External causes of mortality injuries traumatic brain injuries suicidal behavior adolescents

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TIIVISTELMÄ

Ulkoiset kuolinsyyt ovat nuorten aikuisten merkittävimpiä kuolinsyistä matala- ja keskituloisissa maissa. Tässä väitöstutkimuksessa tutkittiin tapaturmaisten vammojen aiheuttaman kuolleisuusuuden ja itsemurhakäyttäytymisen ilmaantuvuuden muutoksia matala- ja keskituloisissa maissa.

Tutkimuksessa I tutkittiin ulkoisten kuolinsyiden kehityssuuntia Seychellien tasavallassa 30 vuoden ajanjaksolla hyödyntäen väestöpohjaisia rekistereitä. Tapaturmien osuus kaikista kuolemista koko väestössä oli 8,5 %. Miesten kuolemat kattoivat lähes 3/4 kaikista tapaturmaisista kuolemantapauksista. Miehillä yleisin kuolinsyy oli hukkuminen, ja naisilla muut tahattomat vammat. Koko väestössä tapaturmaiset kuolemantapaukset vähenivät tarkasteluajanjakson aikana.

Tutkimuksessa II tutkittiin tapaturmaisten aivovammojen aiheuttamien kuolemantapauksien määrien kehityssuuntia Seychellien tasavallassa 30 vuoden ajanjaksolla käyttäen väestöpohjaisia rekistereitä. Miehet kuolivat naisia todennäköisemmin aivovammoihin ja niihin liittyviin muihin vammoihin. Aivovammat aiheuttivat joka viidennen kuoleman kaikista kuolemista, joissa oli ulkoinen syy. Tieliikenneonnettomuudet olivat aivovammojen aiheuttamien kuolemien yleisin mekanismi.

Tutkimuksessa III tutkittiin itsemurhakäyttäytymisen esiintyvyyttä ja siihen liittyviä tekijöitä eräiden matala- ja keskituloisten maiden nuorten keskuudessa hyödyntäen Global School Health Survey -aineistoa. 10–11 % nuorista oli harkinnut itsemurhaa, tehnyt itsemurhasuunnitelman tai yrittänyt itsemurhaa. Alhaisin esiintyvyys havaittiin Kaakkois-Aasian alueella, kun taas korkein esiintyvyys Väli- ja Etelä-Amerikan matalatuloisten maiden alueilla.

Tulokset osoittavat, että matala- ja keskituloisille maille räätälöityjä käytäntöjä tarvitaan tapaturmakuolleisuuden vähentämiseksi. Tapaturmakuolleisuuden tehokas vähentäminen vähentää työikäisten ikäryhmien menetettyjä työvuosia ja tuottaa merkittäviä taloudellisia säästöjä.

AVAINSANAT: ulkoiset kuolinsyyt, vammat, tapaturmaiset aivovammat, itsetuhoinen käyttäytyminen, nuoret

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Abbreviations

AIS	Abbreviated Injury Scale
CDC	Centers for Disease Control and Prevention
DALY	Disability Adjusted Life Years
GDP	Gross Domestic Product
GC	Gini Coefficient
GCS	Glasgow Coma Scale
GSHS	Global School-based Student Health Survey
ICD	International Classification of Diseases
HICs	High Income Countries
LICs	Low Income Countries
LMICs	Low and Middle Income Countries
RTCs	Road Traffic Crashes
TBI	Traumatic Brain Injury
WHO	World Health Organization

List of Original Publications

This dissertation is based on the following original publications, which are referred to in the text by their Roman numerals:

I Anne Abio, Pascal Bovet, Joachim Didon, Till Bärnighausen, Masood Ali Shaikh, Jussi P. Posti, Michael Lowery Wilson. Trends in mortality from external causes in the Republic of Seychelles between 1989 and 2018. *Scientific Reports,* 2020; 10: 22186. doi: 10.1038/s41598-020-79228-8

II Anne Abio, Pascal Bovet, Bernard Valentin, Till Bärnighausen, Masood Ali Shaikh, Jussi P. Posti, Michael Lowery Wilson. Changes in Mortality Related to Traumatic Brain Injuries in the Seychelles from 1989 to 2018. *Frontiers in Neurology,* 2021; 12: 720434. doi: 10.3389/fneur.2021.720434

III Anne Abio, Priscilla Owusu, Jussi P. Posti, Till Bärnighausen, Masood Ali Shaikh, Viswanathan Shankar, Michael Lowery Wilson. Cross-national examination of adolescent suicidal behavior: A pooled and multi-level analysis of 193 484 students from 53 LMIC countries. *Social Psychiatry and Psychiatric Epidemiology*, 2022; 57:1603–1613. doi: 10.1007/s00127-022-02287-x

1 Introduction

Injury-related mortality, also referred to as external causes of mortality whether unintentional or intentional, are a greatly underestimated public health burden and among the leading causes of morbidity and mortality worldwide [1,2]. Within this thesis, injuries are also referred to as external causes of mortality and both terms will be used interchangeably. External causes of mortality account for approximately 5 million global deaths every year which represents 10% of global deaths [3,4]. This estimate is 5 times higher than HIV/AIDS related mortality and 1.7 times higher than the combined mortality attributable to HIV/AIDS, malaria, and tuberculosis [1,5–7].

The highest injury burden occurs mainly in low- and middle-income countries (LMICs), with approximately 90% of global deaths due to injuries occurring in these countries [1,8–10]. It is envisaged that injury rates and the immense burdens that they carry, will continue to rise over the foreseeable future [5]. Several factors have been attributed to the rise in injury-related morbidity and mortality among LMICs [1]. Among them, are unplanned urbanization exacerbated by large scale population migration from rural agricultural areas to cities [11], increased motorization combined with poor separation of vehicular traffic from pedestrians [1,5,6,12,13], the increasing frequency and severity of natural and man-made disasters in increasingly highly populated areas [14–16], and inadequate overall policy attention given to addressing preventable injuries [1,8,10].

In parallel with socio-economic development, it has been speculated that injury mortality increases with the rise in Gross Domestic Product (GDP) per capita, before it starts to decline [11,17]. The GDP growth is usually linked to a rise in industrialization and motorized infrastructure, which leads to an increased incidence of injuries [18,19]. Thereafter, policies and strategies are implemented, for example, road traffic and health safety laws are enforced, which contributes to a decline in injury related morbidity and mortality [18,19]. It is stipulated that over time, significant declines in injury mortality were also observed among pedestrians as opposed to vehicle occupants in the context of traffic crashes in high income countries (HICs) [19]. The decline observed in HICs was also associated with investments in public infrastructure such as separating pedestrian and vehicle traffic, among others which contributed to the declines in pedestrian fatalities [20]. Thus, in

LMICs, the increase in road traffic crashes (RTCs) has been associated with increased economic growth; however, in HICs, economic growth is now linked with a decline in the incidence of RTCs [18,19].

There is variation by region, country and age groups with regard to the leading mechanisms of mortality. For instance, studies conducted in sub Saharan Africa have revealed the leading mechanisms of injuries include RTCs, homicide and drowning, particularly affecting the younger age groups [21]. In contrast, falls are a major mechanism of injury mortality among the elderly in HICs [13]. There may be an overlap between unintentional and intentional external causes of mortality depending on the intent. This means intentionality may be difficult to establish, for example, consider a case of drowning. It could be unintentional if someone was intoxicated and went out for a swim. However, it could be intentional if it was an act of suicide or homicide.

Research on injuries and injury control is under researched compared to other health concerns in LMICs where estimates are often obtained from limited data sources which suffer from incomplete reporting [6,8]. A graphical presentation of the world by income status is shown in Figure 1.

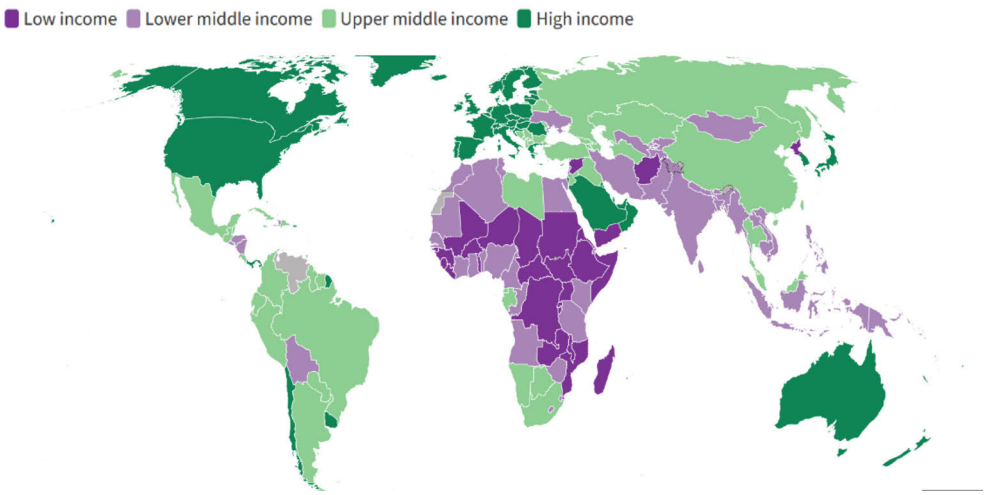


Figure 1: The world map by income, 2021.

Source: The World Bank website on world development indicators [22]

2 Review of the Literature

2.1 External Causes of Mortality

Injuries contribute to a significant amount of morbidity and mortality globally. Injuries often lead to loss of economic productivity in families through treatment costs, disability, time lost caring for injured relatives or days off from work needed to recover, and premature death [23]. This could be attributed to the considerable effort required to restore an individual's health which may include rehabilitation if necessary. The effects of injuries are also associated with psychological stress, anxiety and trauma both to the survivors and their respective families, which may require time to heal [3].

2.1.1 Definition

According to the World Health Organization (WHO), an injury is the physical damage that results when a human body is suddenly or briefly subjected to intolerable levels of energy. It can be a bodily lesion resulting from acute exposure to energy in amounts that exceed the threshold of physiological tolerance, or it can be an impairment of function resulting from a lack of one or more vital elements (i.e., air, water, warmth) as in strangulation, drowning or freezing [24].

2.1.2 Types of Injuries

Injuries are commonly classified according to intent, whether they are intentional or unintentional.

a) Unintentional injuries

   These are unplanned or accidental and include but are not limited to transportation crashes (road, air, water and rail), drowning, accidental poisoning, fall-related injuries, fire-related burns, hypothermia and radiation-related burns [24].

b) Intentional injuries

These are usually premeditated and deliberately done to oneself or by a person to another person or other persons. Examples include interpersonal violence through assault or homicide; self-harm by self-mutilation, suicide, poisoning, drug or alcohol abuse which could result in overdose; legal intervention through the use of extreme force by security personnel or police brutality; and wars, conflict, civil unrest or terrorism [24].

c) Undetermined intent

These are injuries where intentionality is not possible to establish. For example, deaths which occurred as a result of an intentional act, can be misclassified as being unintentional or accidental. Various socio-cultural issues or stigma attached to certain intentional injuries, such as suicide, can mask the nature of injury events. This in turn contributes to the under-reporting of injury mechanisms [25].

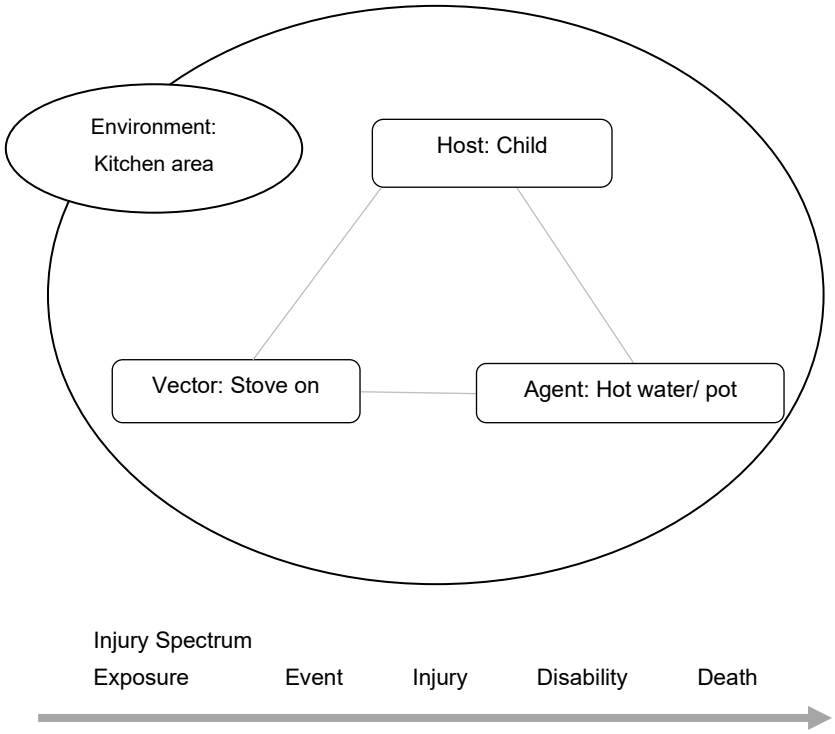


Figure 2: Fire-related burn injury model

Modified from Holder et al., 2001. Injury surveillance guidelines [24]

2.2 Epidemiology of Injuries

Injuries account for 10% of global deaths [3,4]. There exists significant variation between and within world regions with regard to injury prevalence and burden. For instance, injuries accounted for 12% of deaths in the LMICs of the Americas, 11% of deaths in the Low Income Countries (LICs) of South East Asia, and 6% of deaths in HICs in 2008 [3]. In 2010, 9.6% of deaths in the African region were due to injuries [12]. Injuries are among the leading causes of Disability Adjusted Life Years (DALYs) to which they contribute to 10% of disability years [26]. Wang et al., reported, 10% of all deaths in China from 2002 to 2006 were due to injuries [27]. In South Africa, injuries were the second leading cause of deaths and DALYs in 2000 [3,28].

Globally, an estimated 973 million people sustained injuries that required medical attention, of which 5.8% (56.2 million) needed inpatient hospital care in 2013 [4]. The global injury related mortality rates reported ranged from 82.0 – 88.5 in 1990, 73.3 in 2010, and 66.9 – 70.0 per 100 000 inhabitants in 2013 [4,29,30]. Generally, the incidence of injuries has declined globally over time [3,4]. The number of global deaths from injuries increased from a range of between 4.1 million to 4.3 million in 1990, to 5.1 million in 2010 [3,29,30], and reduced to 4.8 million in 2013 [29], and further to 4.3 million in 2019 [31]. The age standardized death rates reduced by 9.3% from 1990 to 2010 [30], and 21.0% from 1990 to 2013 [29], and reduced by 19.4% from 1990 to 2019 [31]. Most of the decline has been observed in HICs, with the reverse happening in LMICs [3,4].

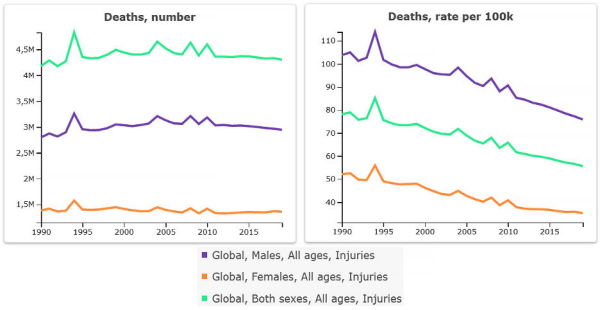


Figure 3: Trends of global injury deaths 1990 to 2019

Created from the Global Health Data Exchange website [32]

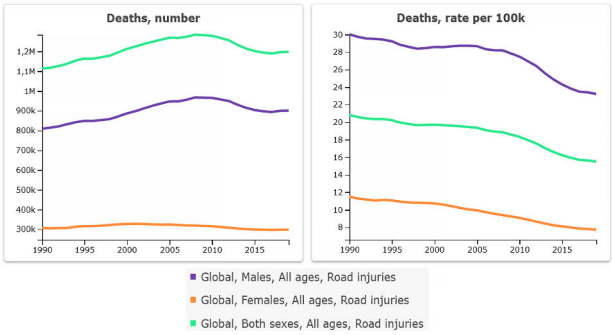
The injury related standardized mortality rate was 116 per 100 000 population in 2012 in Africa [2]. This estimate was higher than any other region in the world which ranged from 49 in the European region to 99 per 100 000 population in the South East Asia region [2]. Moreover, South Africa had an injury mortality rate of 157.8 per 100 000 inhabitants in 2000 [28], which was considerably higher than the global and African average.

2.3 Mechanisms of Injuries

Road Traffic Crashes

RTCs are the leading cause of injuries and death among young adults globally [3,4]. RTCs contribute to approximately 1.3 million deaths annually and constitute a third of all injury-related deaths [3,4,26]. In 2013, RTCs contributed to 29.1% of global injury-related mortality [4]. As recent as 2019, road traffic injuries were the fourth leading cause of DALYs among males globally [31]. Although 60% of the world's vehicles are located in LMICs, these countries collectively have 93% of the global road traffic fatalities [26]. The global road traffic age standardized mortality rate was between 18.4 – 21.3 in 1990, 19.5 in 2010, 20.0 – 20.7 in 2013 and 15.8 per 100 000 inhabitants in 2017 [4,29,30,33]. Moreover, in 2008, the highest road traffic death rates were reported in the East Mediterranean region at 21.6, followed by the Western Pacific region at 21.2, and lastly the African region at 20.9 per 100 000 inhabitants [3]. The regions with the leading road traffic injury related mortality rates in 2017, included North Africa and the Middle East both at 23.2 and sub Saharan Africa at 22.0 per 100 000 inhabitants [33]. Additionally, the countries with the leading road traffic death rates included the Central African Republic, Somalia and the United Arab Emirates at 85.5, 51.1 and 49.9 per 100 000 inhabitants respectively [33]. Iran also had a mortality rate of 26.1 per 100 000 inhabitants in 2017 [33]. Seychelles had an age standardized mortality rate of 13.0 per 100 000 inhabitants in 2017 and 8.6 per 100 000 population in 2013 [33,34].

Globally, the trend of road traffic mortality has not been consistent over time. For instance, the number of deaths increased from 1.1 million in 1990 to 1.3 million in 2010, to 1.4 million in 2013 [29,30], then reduced to 1.2 million in 2017 [33]. The road traffic age standardized death rates increased by 6.2% from 1990 to 2010 [30], although it also decreased by 6.1% from 1990 to 2013 [29], and 29.0% from 1990 to 2017 [33]. The largest decreases between 1990 to 2017 were observed in the high income Asian Pacific region by 70.4%, Western Europe by 68.7% and Central Europe by 56.8% [33]. Although the highest declines were particularly observed in HICs; increases have also been reported over time in some LMICs [4,27,33,35,36]. For instance, the highest increases from 1990 to 2017 were reported in Jamaica, the Dominican Republic and Paraguay by 94.2%, 35.5%, and 31.1% respectively [33]. In contrast, the mortality rate in Iran declined by 51.7% between 1990 and 2017 [33]. Seychelles also had an increase by 15% during the same period [33]. It is anticipated that mortality and morbidity associated with RTCs will continue to rise over time in LMICs, and particularly in the African region [5]. The mortality is in part attributed to delays in access to health care or inadequately equipped trauma care facilities following a road traffic crash [37]. Although the African region has the lowest



motorization rate globally, the road traffic fatality rates are similar to the regions with higher motorization rates [3]. In the same region, RTCs are a leading cause of injury mortality ranging from 22 – 87% [12].

Figure 4: Trends of global road traffic injury deaths 1990 to 2019

Created from the Global Health Data Exchange website [32]

Suicide and suicidal behavior

Suicide is the second leading cause of injury death and a leading contributor to DALYs [3,4], where it contributes to approximately 700 000 global deaths annually [26]. Additionally, it is one of the leading causes of mortality among youth [38]. In 2013, it accounted for 1.5% of deaths globally and was the 13th leading cause of death in 2010, and 22nd cause of DALYs in 2019 [29–31]. There is variation in suicidal behavior mortality by region; for instance, self-harm has been reported more in HICs compared to LMICs [3]. In 2013, self-harm contributed to 17.6% of injury deaths worldwide [4]. The global suicide age standardized mortality rate was 14.5 – 15.8 in 1990, 13.1 in 2010 and 11.8 – 12.2 per 100 000 inhabitants in 2013 [4,29,30]. The highest death rates were reported in Europe at 16.9 and Southeast Asia at 15.6, with a lower rate reported in Africa at 6.3 per 100 000 inhabitants in 2008 [3]. At least half of the suicide DALYs occurred in South and East Asia in 2013 [4]. In 2013, suicide was ranked as the second leading cause of mortality among youth aged 10 – 24 years and accounted for 7.8% and 7.4% of deaths among males and females respectively [38]. It was also ranked the leading cause of death among teenage females (15 – 19 years) in 1990, 2005 and 2013; and also among females aged 20 – 24 years in 2013 [38].

It is anticipated that deaths from self-harm will continue to rise [3]. However, statistics from many world regions are unreliable because of the stigma associated with it [39,40]. Globally, the mortality numbers increased from 712 000 in 1990 to 884 000 in 2010, then reduced to 842 000 in 2013 [29,30]. The self-harm age standardized mortality rates declined by 9.6% from 1990 to 2010 [30] and 23.1% from 1990 to 2013 [29]. However, an increase in suicide was observed during the 2007/2008 financial crisis[4,41]. Within East Asia, suicide rates have declined, while they increased in South Asia between 1990 and 2013 [4].

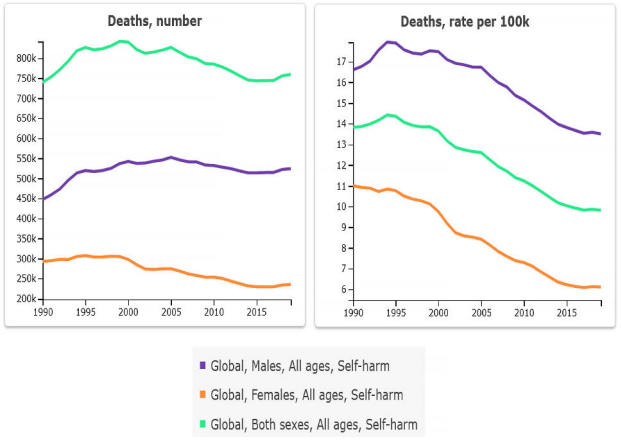


Figure 5: Trends of global suicide deaths 1990 to 2019

Created from the Global Health Data Exchange website [32]

Falls

Falls were the second leading mechanism of unintentional injury death globally in 2017 [3,13]. Roughly 684 000 people die from falls annually, with fatal falls especially affecting people who are aged 60 years and older [26]. Falls contributed to 11.6% of total injury-related deaths in 2013 [4]. The global age standardized death rate due to falls was between 7.8 – 9.0 in 1990, 8.0 in 2010 and 7.8 – 9.1 in 2013 [4,29,30] and 9.2 per 100 000 inhabitants in 2017 [13]. Falls were more commonly reported in HICs at 7.8 and Southeast Asia at 12.0, while the African region had the lowest rate at 2.4 per 100 000 inhabitants in 2008 [3]. In 2017, South Asia had the highest age standardized mortality rate at 22.0, followed by Eastern sub Saharan Africa at 12.2 per 100 000 inhabitants [13]. In 2017, the countries with the highest mortality rates included Solomon Islands at 31.2, India at 25.4 and Vietnam at 18.0 per 100 000 inhabitants [13]. Seychelles had a mortality rate of 6.2 per 100 000 in 2017 [13]. In 2019, falls were the eighth leading cause of DALYs and the leading cause of injury deaths and DALYs among people aged 75 years and older [13,31].

Falls are a burden in HICs and contribute significantly to mortality and disability, for example, in Europe and Asia [3,13]. The global population is ageing over time and gaining more longevity, especially in HICs [42]. Thus, the older population is one of the fastest growing age groups globally. Moreover, HICs also tend to have a

higher life expectancy compared to LMICs, which contributes to the higher rates of falls among the older age groups. Within LMICs, falls are common among children, and 56% of the fall injuries were attributed to children in 2007 [13].

Regarding the trend over time, mortality numbers from falls increased from a range of between 314 000 to 349 000 in 1990, to 541 000 in 2010, and further to 556 000 in 2013, and 696 000 in 2017 [13,29,30]. The age standardized death rates increased by 2.0% from 1990 to 2010 [30], and 3.4% between 1990 to 2013 [29], but reduced by 5.9% from 1990 to 2017 [13]. The regions with the highest increase in falls from 1990 to 2017 were high income North America by 57.2% and Australasia by 32.1% [13]. In sub Saharan Africa, fall related mortality declined by 14.1% [13]. By country, the largest increases in age standardized mortality rates from 1990 to 2017 were recorded in the US at 61.0% and Australia at 41.8%, while the largest decreases were reported in the Czech Republic, Hungary and Armenia by 72.5%, 69.1% and 68.5% respectively [13]. Additionally, within sub Saharan Africa, increases in fall mortality was reported in Ghana, by 14% between 1990 to 2017 [13]. However, within the same region and duration, declines were reported in Cape Verde (35.1%), Rwanda (31.8%), South Africa (25.4%) and Gabon (20%) [13]. During the same period, the mortality rate reduced by 3.6% in Seychelles [13].

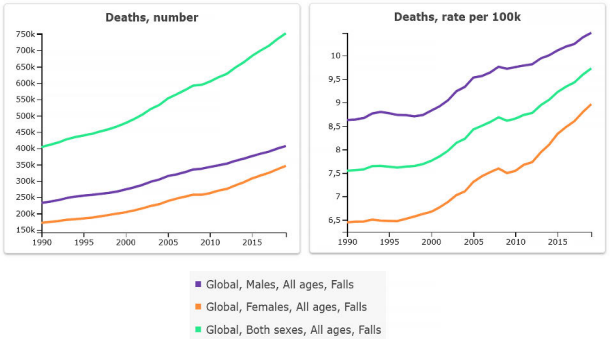


Figure 6: Trends of global fall deaths 1990 to 2019

Created from the Global Health Data Exchange website [32]

Drowning

Drowning causes approximately 300 000 deaths annually, with 450 children dying each day worldwide [43,44]. Drowning is the third leading cause of unintentional injury mortality [43] and reported to be the leading cause of injury death among children in Asia [44]. Higher rates of drowning mortality are common in areas that are close to water bodies [43]. The global drowning age standardized mortality rate ranged from 7.5 – 9.4 in 1990, 5.1 in 2010 and 5.1 – 5.2 in 2013 [4,29,30,43] and 4.0 per 100 000 inhabitants in 2017 [43]. The highest mortality rates were reported in Oceania at 14.5 and Central sub Saharan Africa at 6.0 per 100 000 inhabitants in 2017 [43]. Furthermore, high rates were recorded in the Western Pacific region at

5.7, Europe and Southeast Asia both at 5.5, and Africa at 5.2 per 100 000 inhabitants in 2008 [3]. Collectively, Bangladesh, China, India and Pakistan contributed to 51.2% of global drowning deaths in 2017 [43]. However, this could also be attributed to their large populations in general and proximity to water bodies. In 1990, the countries with the highest mortality rates included Bangladesh (32.2), Cambodia (22.6) and Papua New Guinea (19.3) per 100 000 inhabitants [43]. In 2017, the countries with the highest drowning-related mortality rates included Seychelles and Vanuatu at 11.8 and 11.1 per 100 000 inhabitants respectively [43].

Regarding the trend, the drowning numbers decreased from a range of between 532 000 to 545 000 in 1990 [29,43], to 349 000 in 2010 [30], and further to 361 000 in 2013 [29] and 295 000 in 2017 [43]. Congruently, the age standardized drowning mortality rates reduced by 33.1% from 1990 to 2010 [30], by 46.3% from 1990 to 2013 [29], and 57.4% from 1990 to 2017 [43]. By region, the highest declines in mortality rates between 1990 and 2017 were recorded in East Asia by 64.9%, Andean Latin America by 58.9%, Central Europe by 57.6% and Central Latin America by 57.5% with no regional increases [43]. During the same period, the countries with the highest declines included Singapore by 83.4%, Armenia by 78.7%, Estonia by 77.5% and Maldives by 77.3% [43].

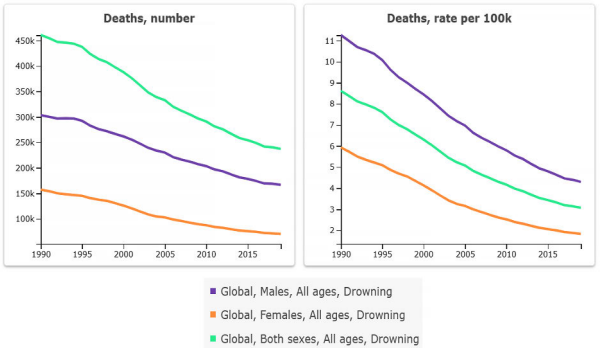


Figure 7: Trends of global drowning deaths 1990 to 2019

Created from the Global Health Data Exchange website [32]

On the other hand, increases from 1990 to 2017 were recorded in some countries like Lesotho (12.5%), Zimbabwe (6.2%) and Tonga (5.7%) [43]. In Seychelles, the mortality rate reduced by 25.7% during the same period [43].

Although Bangladesh, China, India and Pakistan had large numbers of deaths, from 1990 to 2017, the drowning mortality reduced by 70.4%, 65.3%, 50.7% and 43.1% respectively [43].

Fire-related burns

Burns typically occur when one's body comes into contact with heat (e.g. hot liquids, solids, flames or gases), electricity, friction, radiation or chemicals [26,45]. Globally, fire-related burns contribute to 180 000 deaths annually and most commonly occur within homes (especially in kitchens) and workplaces [26,45].

Fire-related burns had an age standardized mortality rate that ranged from 5.3 – 5.9 in 1990, 4.9 in 2010 and 3.3 – 3.5 per 100 000 inhabitants in 2013 [4,29,30]. However, in 2008, the highest mortality rates reported were in the East Mediterranean region at 5.2, the African region at 4.9 and Southeast Asia at 4.8 per 100 000 inhabitants [3]. Fire-related burns are more commonly reported among females and children (mostly from scalds), with the injuries being attributed to the role of women cooking at home and children playing nearby, particularly in LMICs [4,45]. For instance, fire-related burns were among the top 10 leading causes of death (and outranking malaria) among young females aged 15 – 25 years in 1990, 2005 and 2013 [38]. The fire-related death numbers changed from a range of between 280 000 to 300 000 in 1990, to 338 000 in 2010, and to 238 000 in 2013 [29,30]. The corresponding age standardized mortality rates declined by 7.3% from 1990 to 2010 [30] and 41.9% from 1990 to 2013 [29].

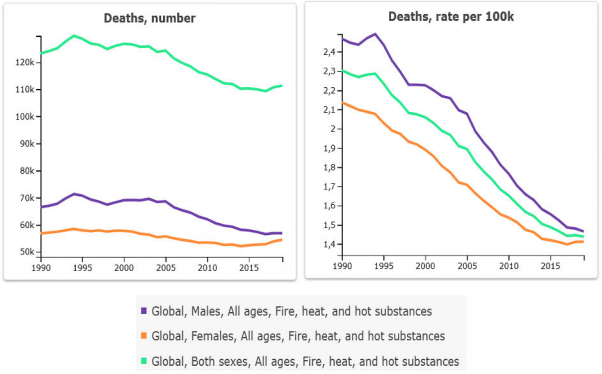


Figure 8: Trends of global fire-related deaths 1990 to 2019

Created from the Global Health Data Exchange website [32]

Poisoning

Poisonings had a global age standardized mortality rate that ranged from 2.4 – 4.0 in 1990, 2.6 in 2010 and 1.4 per 100 000 inhabitants in 2013 [4,29,30]. The highest mortality rates for poisonings have been reported in the LMICs of Europe at 18.1, and a lower rate in Africa at 4.9 per 100 000 inhabitants in 2008 [3]. The number of deaths associated with poisonings changed from 120 000 in 1990, to 180 000 in 2010, and 98 000 in 2013 [29,30]. The age standardized mortality rates declined by 34.4% from 1990 to 2010 and 36.0% from 1990 to 2013 [29,30].

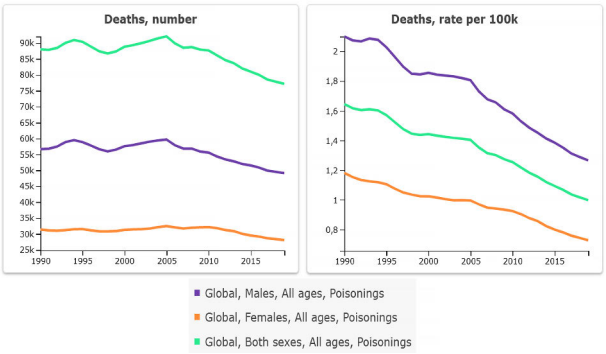
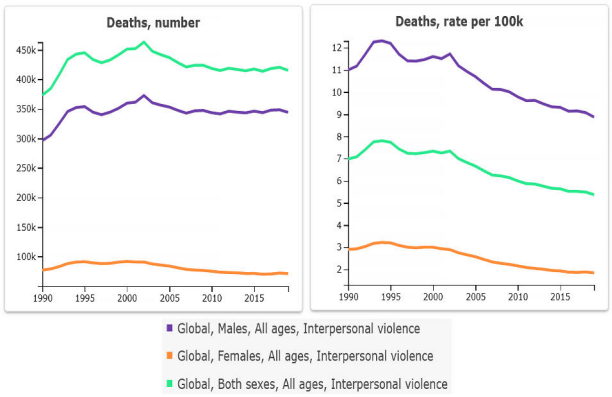


Figure 9: Trends of global poisoning deaths 1990 to 2019
Created from the Global Health Data Exchange website [32]

Interpersonal Violence

Interpersonal violence contributed to 8.5% of injury deaths in 2013 [4]. The global interpersonal violence age standardized death rate varied from 6.6 – 6.7 in 1990, 6.6 in 2010 and 5.6 – 5.7 per 100 000 inhabitants in 2013 [4,29]. Homicide, a form of interpersonal violence was more common in the LMICs of the Americas at 24.1, followed by the African region at 20.1 per 100 000 inhabitants compared to other regions in 2008 [3].



Regarding the trend over time, the mortality numbers changed from a range of 339 000 to 341 000 in 1990, to 456 000 in 2010, and 405 000 in 2013 [29,30]. Furthermore, the age standardized mortality rate declined by 1.0% from 1990 to 2010 [30] and 16.0% from 1990 to 2013 [29,30].

Figure 10: Trends of global interpersonal violence injury deaths 1990 to 2019
Created from the Global Health Data Exchange website [32]

There have been regional variations in violence, for instance, the trend has declined in Asia and Europe but not in other regions, e.g., in Latin America and sub Saharan Africa [4]. Within the African region, South Africa had one of the highest homicide rates at 38.4 per 100 000 inhabitants in 2000 [28,46]. This rate is significantly higher than global and regional average homicide mortality rates.

Other Mechanisms of Injuries

Other types of injuries occur as a result of natural disasters like tsunamis, floods and landslides, as well as conflicts and war which influence rates of mortality and disability [4]. The age standardized death rate for natural disasters was 0.7 in 1990, 2.9 in 2010 and 0.3 per 100 000 inhabitants in 2013 [4,29,30]. The number of deaths associated with natural disasters changed from a range of between 31 000 to 33 000 in 1990, to 196 000 in 2010, then reduced to 19 000 in 2013 [29,30]. This corresponded with age standardized mortality increasing by 336.4% and reducing by 60.4% from 1990 to 2010 and 1990 to 2013 respectively [29,30].

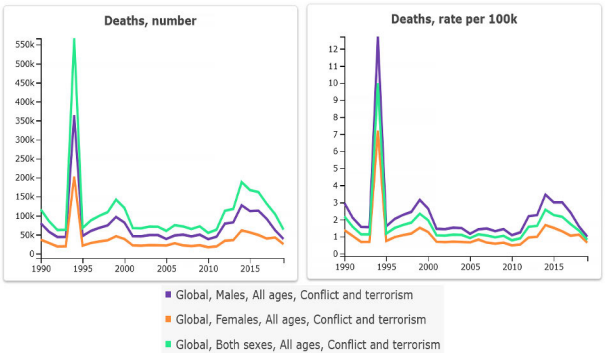


Figure 11: Trends of global conflict injury deaths 1990 to 2019

Created from the Global Health Data Exchange website [32]

Legal interventions through factors like police brutality also contribute to death. Mortality from legal interventions and conflicts contributed to deaths within a range of 64 000 to 72 000 in 1990, to 18 000 in 2010, and 31 000 in 2013 [29,30]. The age standardized mortality rate ranged from 1.3 – 1.5 in 1990, 0.3 in 2010, and 0.4 – 0.5 in 2013 [4,29,30]. The age standardized mortality rates reduced by 79.5% from 1990 to 2010 [30], and 69.3% from 1990 to 2013 [29]. In 2008, the highest mortality rates due to war and conflict were reported in the East Mediterranean region at 17.7, followed by the African region at 3.6 per 100 000 inhabitants [3].

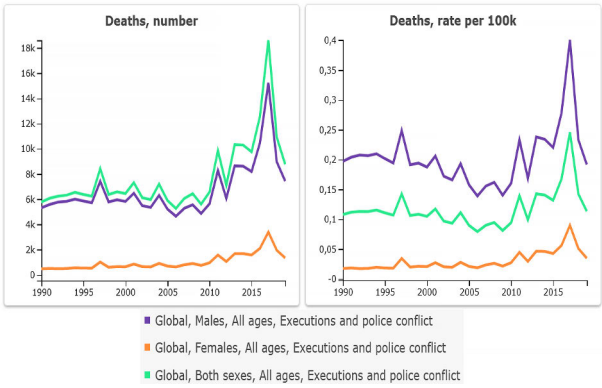


Figure 12: Trends of global execution and police conflict deaths 1990 to 2019

Created from the Global Health Data Exchange website [32]

2.3.1 Risk factors for Injuries

Injuries are associated with myriad risk factors, which tend to vary by region, country and location. For example, areas located closer to water bodies are more likely to report higher mortality from drownings [44].

Males tend to be over-represented in injury prevalence and mortality estimates in general [27,36,47]. Research studies estimated that 56 – 86% of injury deaths occur among males [3,6,48]. This is usually attributed to increased risk taking behavior among males in comparison to females. Males also encounter injuries through high risk occupations such as mining and construction or are more likely to be directly involved in conflict situations like war [49]. Furthermore, busy areas with limited pedestrian safety are more likely to have injury casualties.

Adolescents and young adults (10 – 29 years old) are especially affected by injuries as well as those in the economically productive age groups 30 – 49 years [31]. Globally, among young people aged 10 – 24 years, 40% of the deaths recorded were due to injuries in 2004 [3]. For instance among males, road traffic crashes (18.3%) and suicide (7.8%) were the leading causes of death among the youth aged 10 – 24 years in 2013 worldwide [38]. On the other hand, suicide was the second leading cause of death among females within the same age group in 2013 [38]. Moreover, in 2019, road traffic injuries were the leading cause of DALYs, suicide the third while interpersonal violence was the fifth leading cause in this age group [31]. RTCs were also the leading cause of DALYs for those aged 25 – 49 years in 2019 [31]. Children are prone to drowning particularly in Eastern Europe and Southeast and East Asia [38,44,50] and burn injuries in LMICs [45]. Furthermore, the older population over 60 years of age are prone to falls in HICs [3,13].

Co-morbidities also contribute to the incidence of injuries. For instance, among the older populations, co-morbidities coupled with medication use and issues related

with balance contribute to falls [13]. In LMICs, epilepsy is a contributing factor to burn injuries especially when the victim is left alone or unsupervised [45].

Lower social economic status has been associated with injuries. According to Rybarczyk et al.;, patients admitted to hospitals for burn injuries were more likely to have a low socio-economic status and reside in a rural area within the African region [45]. In HICs, drowning was associated with low socio-economic status, residing in rural areas, and intoxication with alcohol [44]. The socio-economic disparities are also related to the distribution of wealth in an area and the ownership of resources like land, among others, which lead to the disadvantaged resorting to crime and violence. The additional access to resources influences the ability to obtain health care in case of injuries which may ultimately contribute to death. According to a systematic review from the African region, patients with burns were more likely to be from larger households [45]. It is quite common to have a household comprised of several extended family members in the African region.

Substance abuse and alcohol use are associated with the injury prevalence and mortality [10,51,52]. A WHO study found the alcohol involvement prior to an injury ranged from 6 – 45% among patients in various countries [51]. Krebs et al. reported that the suspected rate of alcohol use among TBI patients was 23% in a Rwandan hospital [10]. The use of alcohol and drugs may inhibit one's ability to act swiftly if in imminent danger of an accident or could escalate risky behavior through poor judgment thereby increasing the injury risk [19,53]. Furthermore, the use of illicit drugs like cocaine could lead to accidental poisonings and overdoses that may potentially result in death [53].

Thus, awareness about the factors that increase the risk of injuries is an important element to developing strategies that could minimize the eventual occurrence of injuries and premature death among the high-risk groups.

2.3.2 Future of Injuries

It is anticipated that while injuries will continue to rise in LMICs, they will gradually decline in HICs [3]. The increase in road traffic fatalities has been attributed to a rapid increase in motorization and unplanned urbanization, lax implementation of law enforcement policies, inadequate access to health care services in case of injuries and inefficient implementation of injury prevention policies in LMICs [3]. Other factors that influence intentional injuries include wealth, socio-economic status, cultural situations, influence from social media, availability of mental health services, and availability to weapons or products that can be used for self-harm and lethality e.g., access to fire-arms, pesticides and poisons [4,39]. It is important for prevention policies to focus on the mechanisms of injuries that are dominant given the various contexts by reducing the occurrence of the injury as well as effective

rehabilitation once an injury has occurred [3,4]. For instance, after the introduction of the mandatory use of helmets in Vietnam, the deaths from RTCs decreased by 16% [3].

2.3.3 Injuries and their prevention

Injuries are preventable and the implementation of adequate policies or strategies would go a long way in reducing the associated mortality. The prevention strategies could involve various targets, for example, the individuals, communities and government sectors, like the health, education or transport sectors.

Awareness of individual risky behaviors and their respective health consequences is important, e.g., over speeding, drink driving and swimming while intoxicated could influence the occurrence of injuries. Beyond individuals, an effective preventive strategy involves the reduction of the amount of force that is exerted from an object to a person. For instance, during a car crash, an airbag minimizes the impact on a passenger, while a seatbelt would help to prevent a passenger from penetrating the windscreen. This would prevent additional injuries that the passenger might have encountered had they not been held in place by the seatbelt.

Prevention of injuries contributes to improved health outcomes and economic benefits for families, communities and countries as well as social cohesion. This is because breaking the injury and violence cycle potentially reduces the risk of substance abuse, disability, need for rehabilitation, and the stress or anxiety that tends to be associated with injury outcomes [26]. Injuries occur on a spectrum, often starting with exposure to the mechanism that causes the injury, then the actual event that leads to the injury, the potential disability as a result of the injury and death as the worst outcome [24].

Traffic calming measures, for example, have been known to reduce the occurrence of injuries and fatalities [54]. Traffic calming is when physical measures are put in place to reduce the negative effects of motor vehicles while in use, and the improvement of conditions for road users to minimize any occurrence of injuries that could affect them [54]. The reduction in fatalities is associated with the slower speeds used by vehicles as the impact velocity during a crash plays a crucial role in injuries and fatalities [54].

In injury prevention, it is important to consider primary prevention where measures are put in place to prevent or minimize the occurrence of the injury. An example of this is separating pedestrians from direct traffic by creating separate routes for vehicles and pedestrians. Secondary intervention would require immediate post-injury care as soon as the injury has occurred. For instance, in case of a burn, by applying first aid on the burn injury to prevent further physical damage or

infection. Thereafter, tertiary prevention would require managing the final outcome of the injury, for instance, rehabilitation if necessary to prevent additional complications. Using an example of fire-related burns, prevention at different levels is presented in Table 1.

Table 1: Fire related burns Haddon's Matrix example.

	HOST	AGENT	PHYSICAL ENVIRONMENT	SOCIAL ENVIRONMENT
PRIMARY PREVENTION	Kitchen experience and knowledge of fire hazards, experience with different types of cooking fuels and flame behavior; overall health status (eyesight, hearing, sense of smell)	Stove insulation, fire alarms in the kitchen or building	Stove installed high beyond reach of young children	Advise children to stay away from stoves and hot surfaces in the kitchens
SECONDARY PREVENTION	Human tolerances to burns, wearing gloves, keeping children away from hot surfaces and objects.	The use of pots with insulated handles	Presence of fixed objects near stoves, unsecured objects near hot surfaces	Inspection of kitchens to assess if they meet basic standards
TERTIARY PREVENTION	Consequence phase risk communication: rapid mental health response (i.e., counseling), including for those with visible and/or physiological damage due to burn injuries	Availability of fire-blankets in the kitchen areas	Stoves designed with materials to avoid explosions	Public support for trauma care and rehabilitation

Modified from Holder et al., 2001. Injury surveillance guidelines [24]

Considering that the numbers of unintentional injuries, (e.g., road traffic injuries), the bulk of which occur in LMICs and are predicted to rise, it is important to focus on these regions with effective measures before a decline can be observed. The core of preventive measures could focus on the injuries that are dominant, for instance, road traffic injuries. Effective measures that reduce the occurrence of road traffic injuries include minimizing drink driving, use of helmets, use of seatbelts and reducing speed [3]. As such, the WHO has taken the lead in collaborating with governments from LMICs to implement these measures in order to reduce the fatalities from RTCs [3].

The health sector is crucial in the prevention of suicide through the provision of adequate mental health services [3]. However, adequate mental health services for adolescents are key in preventing self-harm among adolescents and youth. The

education sector, via school settings could ultimately support the reduction of suicide rates through the provision of counseling services. However, community programs could also focus on adolescents who are not in school due to various reasons. Other strategies like limiting access to fire-arms, protecting against falls from heights with boundaries, and restricting access to pesticides can reduce suicide rates depending on the setting and context [3].

Swift access to medical care after injuries as well as adequate and affordable healthcare or rehabilitation services contributes to reducing fatalities [3]. Within HICs, pre-hospital management, ambulance services and post-hospital care and rehabilitation services are usually embedded within the health systems [3]. This differs in LMICs where they tend to be separate or independent [3]. The inadequate health care contributes to the higher rates of mortality and disability that are often reported in LMICs. Thus, the solutions would need to be suitable and tailored to resources available in LMICs.

Furthermore, the preventive measures for injuries also lie outside health sector settings which require collective efforts. Education and advocacy in other fields are important, for instance, improving life skills for swimming, surrounding swimming pools with a protective barrier, and installing fences and protective equipment around playgrounds to minimize falls for children [3]. Regarding fire-related burns in households, use of smoke alarms and controlling hot water temperature in residential spaces have reduced burn injuries, especially in HICs [3,55].

Thus, strategies targeting the leading mechanisms of injuries as well as establishing or strengthening innovative schemes for effective prevention programs within the context of LMICs is crucial. In addition to expediting adequate care for injury patients, the availability of reliable information could contribute towards developing efficient societal policies and resourcing for medical emergency services tailored to the regions from which the data are collected.

2.4 Traumatic Brain Injuries

Traumatic brain injuries (TBIs) are a major public health concern globally. TBIs are caused by an external mechanical force against the head that interferes with the functions of the brain [52,56,57]. The consequences of TBIs could be long-term disability, need for long-term care, and loss of economic activities which often impose a significant socioeconomic burden on individuals and societies [58]. Although there has been an increase in TBIs among older adults, a significant number of victims are children or working-age adults [59,60].

TBIs significantly contribute to morbidity, mortality and disabilities among the survivors [52,56,58,61]. Based on hospital patient data, it is estimated that 1.1% of the US population lives with a disability due to a TBI [58,62]. Severe TBIs have

been associated with higher rates of mortality and a poor prognosis or outcome [56,57]. TBI is a dynamic disease: primary injury occurs at the time of the head impact and results in direct damage to the neural tissue of the brain, whereas secondary injuries develop from minutes to months after the mechanical trauma and may contribute to neurological impairment for years [58]. It is also considered a chronic condition owing to the potential for lifelong negative outcomes [58]. In about 10 – 30% of patients with TBIs, it has been identified as a trigger for progressive neurological deterioration and as a risk factor for progressive neurodegenerative disease [58]. The diseases include Parkinson's disease, Alzheimer's disease, dementia, post-traumatic epilepsy, stroke, psychiatric illnesses and neuroendocrine disorders as well as a reduced life expectancy [58]. Individuals with a previous history of a TBI had an increased risk for Alzheimer's disease, although a weak or no relationship has also been found in some studies [58]. Additionally, an increased risk of developing Parkinson's disease has been found among patients with a history of TBI [58].

TBIs also contribute to psychological issues, mental health issues and neurocognitive deficits, like distractions, impulsivity and poor decision-making [58,61]. These impairments are likely to influence survivors' personal relationships and affect social integration measures in their daily lives [58,61]. Additionally, a significant number of people live with unacknowledged TBI sequalae [58]. Longitudinal studies have shown that following severe TBIs, 32% of patients had experienced severe disability, while 40% had moderate disability [52]. This indicates a significant magnitude of care that would be required by individuals in the event of TBIs.

2.4.1 Severity of Traumatic Brain Injuries

TBIs can be classified as mild, moderate or severe depending on their initial severity; however, there are varying viewpoints [62,63]. Generally, 70 – 90% of TBI cases are considered as mild, while 10 – 20% are reported as moderate or severe [52]. The Glasgow Coma Scale (GSC), the length in the loss of consciousness and the length of post-traumatic amnesia are used to measure the clinical severity in an acute phase [62,63]. They provide information on the brain activity and could give differing information on TBI severity [63]. For instance, a long post-traumatic amnesia duration may be identified as signifying severe TBI while at the same time a high score GCS may be recorded in the same patient [63]. Another method used to estimate the TBI severity is the Abbreviated Injury Scale (AIS) score [62].

The GCS is a method that is used to gauge the level of consciousness in a patient and has a score from 3 – 15 [62,63]. When using the GCS alone, a GCS score of 13 – 15 is classified as mild, a score of 9 – 12 as moderate while a score of 3 – 8 is

severe [52,56,60,62]. The timing of the GCS is very important, for instance, if it is done immediately after the injury or a couple of hours or days after the injury [63]. For example, a score taken five minutes post an injury would have a different implication compared to a score taken after resuscitation [63]. The GCS is also normally influenced by intubation or sedation that may be conducted during transportation [63]. Furthermore, the GCS is better at predicting outcome in terms of morbidity or mortality for younger patients as opposed to older patients [64].

The post traumatic amnesia can be reflected by a deterioration in memory, attention, restlessness and agitation, among others [63]. It is a good tool to predict cognitive outcome following TBIs [63]. The severity of the TBI normally varies with the length of the amnesia, however they are based on varying classifications [63]. For example, some classifications describe moderate TBI as based on a length of 1 to 24 hours, while others are based on more than 24 hours [63]. Others consider a loss of consciousness for 30 minutes or less and/or a post traumatic amnesia of less than 24 hours as mild [62]. The challenge with post traumatic amnesia as a measure of TBI severity is that few studies have investigated the comparison of tools used to assess it in terms of being reproducible and reliable [63].

The AIS is an assessment tool that scores the injury based on the anatomical region, imaging or intraoperative findings [65]. The AIS scores categorize the TBI severity into six categories; which includes the mild, 1; moderate, 2; serious, 3; severe, 4; critical, 5; and maximal, 6; categories [62,65]. The injuries in the maximal category are considered as untreatable [62]. These scores are also normally grouped into the mild, (1 and 2); moderate (3) and severe (4 to 6) categories [62].

The data source is an important factor in determining TBI severity [62]. For example, when one has access to the full medical reports, the GCS can be used, while the AIS scores can be used in the presence of administrative databases [62]. Moreover, the post traumatic amnesia and loss of consciousness can be used using information from self-reported questionnaires [62].

Furthermore, the severity of TBI can be assessed from different points of view depending on the assessor [63]. For instance, family members may consider behavioral changes following a TBI as a major issue in a given patient, while a health professional may assess the patient to have minor challenges, and a psychologist may consider the same patient to have significant cognitive challenges [63].

When determining the severity of TBIs, there are other factors that influence the assessment of the GCS and post-traumatic amnesia. To illustrate, intoxication could influence disorientation, sleepiness or memory, which may affect the diagnosis of TBIs with an overestimation or underestimation [63]. Other factors in determining the TBI severity include the use of medications (e.g. sedatives or surgical measures), and language or hearing problems [63]. These factors may also collectively influence the outcome of patients after a TBI [63].

Ultimately, the different measurement methods used contribute to some challenges in estimating TBI severity [62]. This is attributed to the different definitions and case ascertainment used, the varying methods used in data collection, irregular documentation of TBI cases and non-standardized data, among others [59,62]. Nonetheless, the current data and methods available are a starting point that can be improved with continuous research.

2.4.2 Outcome of Traumatic Brain Injuries

Several factors contribute to the long-term outcome after a TBI. These factors could be individual and range from psychological, social, and genetic to biological [63]. In general, the outcomes of TBIs vary by patients [62]. However, individuals who are diagnosed with a TBI at older ages tend to have worse outcomes [58,64]. The worse outcomes in this age group are also associated with pre-existing comorbidities they may have which influence recovery [64]. An improvement or deterioration in functional outcomes in an individual can also be observed over time [58]. Moreover, it is also possible for some older patients to have outcomes that are similar to the younger patients [64]. After 1 to 20 years of follow up among TBI patients, other risk factors for death included drug and alcohol abuse before the injury, epilepsy before the injury, age, social isolation, a higher degree of disability when discharged and functional dependence, and previous head injury admissions [58].

The CRASH-model and IMPACT-calculator are some of the tools that can be used to predict the long-term outcome after TBIs [63]. The tools use various factors or variables that contribute to long-term outcome, for example, brain imaging results, other injuries, co-morbidities and age [63]. Mild TBI is less accurately predicted compared to moderate and severe TBIs based on the prediction algorithms [63]. Support networks, coping skills, resilience and pre-trauma cognitive factors contribute to the predictive values in long-term outcomes for mild TBI [63]. Large population multivariate model studies have predicted mortality or poor outcomes at an accuracy of 80 – 90% [63].

It is also possible for mild TBI to progress to a fatal outcome, however, this occurrence is uncommon [58,63]. Additionally, patients are less likely to recover from a first TBI if they are continuously exposed to TBIs, for instance, through sports activities, like boxing [63]. Moreover, modifications in brain functions can occur when an individual continues to experience head impacts even without any clinical signs of a brain injury [63]. The risk factors that contribute to an outcome vary over time in the course of the injury, for example, immediately after the TBI versus later [63]. With the former attributed to physiology, and the latter to co-morbidities and psycho-social as well as environmental factors [63]. Furthermore, repeated mild TBIs or severe TBIs could lead to gradual neurodegeneration in an individual [63].

The risk of mortality is higher among patients with moderate and severe TBI when the rehabilitation population is considered [58].

Due to the flaws in the measurements of TBI severity, a "risk label" based measure has been proposed [63]. The risk based label acknowledges that there are risks and uncertainties that are encountered with good or bad outcomes regardless of TBI severity [63]. The proposed labels include low-risk TBIs, medium risk TBIs and high risk TBIs instead of the conventional mild, moderate and severe TBIs respectively [63]. This would indicate that it is possible for a low risk (or mild TBI) to result in a bad outcome, and a high risk (or severe) TBI to result in a favorable outcome [63]. Ideally, the risk based grading approach would also need to contribute information to the treatment interventions that could be given to patients [63]. It would also acknowledge the possibility of long term or permanent challenges, but also a critical condition; both which are different situations [63].

2.4.3 Epidemiology of Traumatic Brain Injuries

Globally, 50 – 69 million cases of TBI occur annually [57,66,67]. This implies that 50% of the population are likely to experience a TBI during their lifetime [56,57,67]. The annual incidence is 939 cases per 100 000 population [66]. The estimated annual number of cases in LMICs was at 49 million people, and 7 million in sub Saharan Africa [66]. Within the European Union, an estimated 1 million patients are hospitalized annually due to TBIs [68], and by country, the incidence ranges from 150 to 300 per 100 000 population [60]. A meta-analysis in Europe revealed a hospital incidence rate of 235 per 100 000 population [61]. In 2016, the reported global incidence was an age standardized rate of 369 per 100 000 population, with the highest rates reported in Central Europe at 857 per 100 000 population [49]. The highest country incidences were reported in Syria and Slovenia at 1 322 and 1 092 per 100 000 population respectively in 2016 [49]. Within sub Saharan Africa, an incidence of 326 per 100 000 population was reported, with the highest country rates being recorded in Somalia and Equatorial Guinea both at 402, and South Sudan at 383 per 100 000 in 2016 [49]. During the same year, an incidence of 312 per 100 000 was recorded in Seychelles [49].

Furthermore, a TBI mortality rate of 11.7 per 100 000 population was reported in Europe, with the country rates varying from 3.6 to 21.8 [69]. In Europe, the TBI related mortality rate has ranged from 3.3 to 28.1 per 100 000 population per year [59]. It is estimated that 1.7 million TBIs occur in the US annually, of which, 3% result in death [56]. TBIs contributed to 30.5% of injury deaths in the US between 2002 to 2006 [56]. In 2017, TBIs contributed to 2.7 million deaths in the US, which was equivalent to 2.2% of all deaths [70]. Thirteen percent of the TBI hospitalizations that occurred in Australia led to deaths from 1998 to 2011 [71].

Severe TBIs could contribute to as high as 20 – 40% of mortality among cases [57,72]. The odds of mortality among TBI patients was twice compared to the general population, with an average life expectancy of 7 years in the US [58,73]. TBIs also have economic consequences both at the individual and national levels. For example, it is estimated that 400 billion US dollars are spent on TBIs globally, amounting to 0.5% of the gross world product [56,57].

The TBI incidence increased globally by 3.6% from 1990 to 2016 [49]. The highest increases from 1990 to 2016 were reported in East Asia by 33.3%, and by country in Syria and Yemen by 424.8% and 99.0% respectively [49]. The high rates in Syria and Yemen were associated with conflict [49]. During the same period, the incidence in high income countries declined by 9.4% [49]. Within sub Saharan Africa, the incidence declined by 11.8%, but increased by 37.7% in Seychelles [49]. The trends in TBI mortality have declined in high income countries, owing to improved hospital management and various legislation relating to road safety and occupational safety at workplaces [57]. The injury prevention measures include instituting laws on the use of seatbelts, helmets, drink-driving as well as the use of airbags [62]. A decline in the TBI mortality rates has also been reported in Finland [67]. Furthermore, a decrease in the incidence of TBI has been observed in the United States during the last 20 years [56,62], and a current living systematic review article suggests a similar trend Europe [59]. However, the trends in TBI mortality have increased between 2006 to 2014 in the US; according to the CDC [74].

It is estimated that the global TBI incidence as a whole is increasing as the population ages at an accelerating rate in HICs [49]. In LMICs, traffic is being rapidly motorized in both metropolitan and rural areas [49]. During the 2000's, the ramifications from TBI-related hospitalizations during the younger and the older years of life have been experienced across the human life span [67]. Older adults are the fastest-growing age group worldwide [71,75,76]. The emerging population growth among the elderly is likely to have several consequences for societies and their respective systems which includes but is not limited to health care and pension [76]. The most common geriatric mechanism of TBI is a fall from standing or low height [64,71]. In the United States and many European countries, an increase in TBI occurrence attributable to falls among elderly has been reported [60]. In HICs, incidence of TBIs and hospitalization among the elderly is increasing [59,76]. For example, in Finland, the incidence of TBIs requiring hospitalization in people aged 70 years and older was 283 per 100 000 person-years and increased by 3% annually between 2004 and 2016 [76], while at the same time a decrease in the incidence of TBI in working-age people was observed [67,76].

In general, there is variation in the rates recorded, which could be attributed to the differences in the determination and definitions of cases in different countries and regions [59]. Other factors that influence the rates are the source of data, for

instance, hospital versus national survey data, as well as methodological factors , e.g., if age-adjusted methods were used [59]. Moreover, there is a paucity of information on the magnitude of TBIs at global and regional levels, especially in LMICs [49]. Additionally, epidemiological data through monitoring strategies are largely unavailable, with data mostly available via hospital registries in LMICs [61]. This means that cases who fail to reach the hospital are missed, more so in LMICs, and ultimately this affects the quality of records, policies and interventions required. It has been estimated that due to cases which do not reach the hospitals, the actual number of TBIs maybe at least three times higher than the reported numbers [58]. In a New Zealand study, 30% of individuals who had been involved in an accident that affected their upper bodies and sustained mild TBIs did not seek medical treatment [49]. Moreover, the severe cases who die before reaching the hospitals end up unregistered, as well as cases with mild TBIs [49,61]. Thus, the TBI incidence reported may be under-reported in some instances. Within the hospital records, TBIs can be identified based on the International Classification of Diseases (ICD)-9 or ICD-10 codes [59]. However, the ICD coding system appears sensitive to the type of TBI, with better accuracy for severe TBIs and a number of false-positives and false-negatives reported for mild TBIs [61].

2.4.4 Risk factors for Traumatic Brain Injuries

By gender, males tend to have higher rates of TBI mortality which is consistent with injuries in general [60,62,74,77]. Males are more likely to engage in risky behavior or are more exposed through environmental situations which increases their risk for injuries and TBIs [59]. In studies with older populations in HICs, high rates among females or rates similar to males are more likely to be reported due to unintentional falls [59,64,71].

There is variation in the age groups most likely to be affected by TBIs. The youth or young adults are particularly affected by TBIs as a result of road traffic crashes [52,64]. Teenagers aged 14 – 17 years with TBIs were mostly involved in road traffic crashes in a study conducted in Spain [77]. Additionally, the youth are likely to sustain TBIs through sports and leisure activities that they engage in during their daily lives [67]. Another peak is among infants and children, and the elderly [61]. Children aged 0 – 17 years contributed to 4.5% of the TBI mortality in the US in 2016 and 2017, with motor vehicle traffic crashes as the leading mechanism of injury [78]. In contrast, falls are considered the leading cause of TBIs among the elderly [52,61,71,79]. Adults 65 years and older accounted for 50.3% of the unintentional fall mortality in the US from 1995 to 2001 [62]. Moreover, elderly patients are less likely to survive or have worse outcomes, and are discharged later or have a longer duration of stay from the hospitals following TBIs [68,71,76].

Altogether, a majority of the fatality and severe cases of TBIs occur within LMICs as opposed to HICs [61]. Other factors associated with sustaining TBIs include lower socio-economic status, alcohol use, substance abuse and pre-existing psychiatric disorders [52].

2.4.5 Mechanisms of injury for Traumatic Brain Injuries

TBIs are caused by both penetrating and blunt force mechanisms. Similar to the mechanisms of external causes, the major causes of TBIs include but are not limited to road traffic crashes, falls, homicide, self-harm and sports-related injuries [49,52,74,78].

Unintentional falls are one of the leading causes of TBIs in HICs, while road traffic injuries tend to be the leading cause in LMICs [61,66,80]. The trends of TBIs are gradually increasing globally owing to road traffic injuries, particularly from LMICs [61]. However, TBIs associated with traffic injuries have declined over time in HICs [59,61]. The improved road safety regulations in HICs have led to a decline in the incidence of road traffic related TBIs, while the advanced hospital care has also improved outcomes [57,61,77].

Considering the various factors associated with TBIs within the context of LMICs, it would be of great importance to establish or strengthen road safety and preventive measures to prevent injuries from road traffic collisions, in addition to improving healthcare services.

2.5 Suicidal Behavior among Adolescents

Suicide is a public health problem among adolescents globally. In 2013, approximately 59 000 deaths occurred among adolescents aged 10 – 19 years and it accounted for 6.1% of the all-cause mortality globally [50]. Eighty-nine percent of suicides occurred in LMICs in the same age group in 2013 [50]. The most common methods for suicide include poisoning, hanging and the use of firearms [81]. Suicide is associated with gender-based violence, financial constraints, chronic illnesses, mental health problems and the availability or access to materials needed to self-harm [81]. In some African countries, stigma is often associated with mental health problems, which limits health seeking behaviors among those affected [82]. Suicide is also considered a criminal offense in some countries, with survivors being criminalized instead of being offered help and treatment [40,81,82]. In terms of data, there could be under-reporting or misclassification of data in light of the illegality of suicides in such countries [81]. According to the ICD-10, suicides have been misclassified as undetermined intent, unknown cause, accident or homicide [81]. In

general, suicide studies have been more frequently conducted in HICs as opposed to LICs which could be attributed to the availability of data.

Suicide tends to occur along a spectrum with the suicidal behaviors not necessarily being mutually exclusive [83,84]. Suicidal behaviors are related to one another and ideation typically precedes planning, planning precedes attempt, and an attempt precedes a suicide; however, a suicide can also occur without these stages [83,84]. Suicide ideation is defined as thoughts or desires or a wish to die or a threat to take one's own life [83]. Planning a suicide also involves thoughts of how to die or the method that can be used to end one's life [83]. Attempting suicide involves implementing a method of self-injury with an intention or threat to end one's life that may or may not result in death [83]. A suicide results in death and is normally stated as such in a death certificate. However, a suicide attempt does not always precede a suicide death since other factors are also considered such as the lethality of the method selected.

2.5.1 Suicide epidemiology among adolescents

Suicide also ranks highly as one of the leading causes of mortality among young people. Globally, suicide was the second leading cause of death (after RTCs) among adolescents aged 15 – 19 years, contributing to 7.9%, 8.8% and 8.4% of deaths in 1990, 2005 and 2013 respectively [38]. However, by gender, self-harm was one of the leading causes of death among females aged 15 – 19 during the same time periods [38]. Additionally, it was among the top five cause of DALYs among the 15 – 19 year old teens during the same period [38].

In 2013, the global suicide age standardized mortality rate among adolescents 10 – 19 years was 4.9 (5.0 in LICs and 4.4 in HICs) per 100 000 inhabitants [50]. In the mid-1990s, the suicide rate among adolescents 15 – 19 years old was 11 per 100 000 and reduced to 7.4 per 100 000 by 2002 in the US [85]. The specific reason for the decline is unknown though it could be attributed to an increase in the use of antidepressants from 1987 to 1996 [85]. Furthermore, suicide awareness programs were introduced in high schools within the US [85]. Suicide rates vary by region and country [86]. Asia tends to have the lowest rates of suicide while higher rates have been reported in North America [85]. However, a global study among youth found that suicide was one of the leading causes of death among adolescents 10 – 19 years in some Asian and Eastern European countries [50]. For instance, within this age group, suicide was also the leading cause of mortality in India (11.4), Russia (10.3), Nepal (10.1), Bangladesh (9.6), South Korea (4.2) and Japan (4.0) per 100 000 inhabitants in 2013 [50]. It was also reported as being one of the leading causes of death among young people in Europe and North America [50]. The high rates of

suicide have been attributed to the availability of firearms, substance abuse and low social integration among adolescents [85].

In the US, there is also emerging research concerning the over prescription of psychoactive medication among school-aged children [87]. Furthermore, a US study found that 66% of children aged 6 to 11 years with no psychotic disorders had been given antipsychotic prescriptions and foster children were overly given the medications [87]. Antipsychotic medication increases the risk of death among children and equally exposes them to additional risks for side effects or long term effects for which outcomes have not yet been clearly identified [87].

2.5.2 Suicide Ideation

Suicide ideation is a thought process that occurs prior to a suicide attempt. During this time, an individual contemplates ending their life. Suicide ideation does not usually result in an attempt but could serve as a predictor. Among the cross-sectional surveys conducted among adolescents, the prevalence of suicide ideation has ranged from 3.1 to 33.7% with variations by region [83,84,88–91]. Within the studies from LMICs, the rates were higher in the African region at 20.4% as opposed to the South East Asian region at 8.0% [84].

2.5.3 Planning Suicide

Planning to carry out a suicide attempt is one of the factors that happens in the course of suicidal behavior. This involves planning how to harm oneself with death as a potential desired outcome. Surveys conducted among adolescents have reported a prevalence ranging from 4.1 to 39.8% [84,88,90]. Among adolescents who made suicide plans, higher rates were reported from the African region with a prevalence of 23.7% [84].

2.5.4 Attempted Suicide

It has been assumed that social-cognitive changes can lead to internal downcast moods, which in turn is associated with self-blame when interpersonal stressful situations occur and ultimately result into suicidal behavior in some instances [85]. The prevalence of attempted suicide among adolescents has ranged from 2.2 to 61.5% within LMICs [84,88,89,92,93]. A higher prevalence of suicide attempts has been reported in the Western Pacific region, with a fifth of adolescents reporting at least one attempt in the 12 months preceding the survey [84].

2.5.5 Risk Factors for Adolescent Suicidal Behavior

The individual risk factors, socio-demographic risk factors and contextual risk factors mentioned below are relevant to adolescents globally.

Individual Risk Factors

A previous suicide attempt is one of the major risk factors for suicide [85]. For instance, 25 – 33% of suicides that occurred had a prior attempt or the odds of suicide were 18 times higher among those with a prior attempt [85].

Mental health disorders like depression, anxiety and stressful situations also contribute to the risk of suicide attempts [85]. More depressive symptoms have been found among patients who had multiple suicide attempts compared to patients who had not attempted suicide [85]. Psychological autopsies from suicide deaths found major depression was prevalent at 23 – 52% [85,94]. While anxiety was also more prevalent among repeat suicide attempters, conflicting results with no difference among non-suicidal individuals was found in an outpatient study [85]. Therefore, the recognition of the psychiatric factors that trigger suicidal behavior needs to be addressed among adolescents and young people to reduce the prevalence rates.

Emotions such as hopelessness, anger and low self-esteem are likely to influence suicidal behavior [85]. An assessment of multiple suicide attempters found they had high scores for feeling hopeless, anger or lower self-esteem [85]. Furthermore, trait anger, which was defined as anger that was characteristic of the adolescents' behavior, was observed among repeat suicide attempters compared to other inpatient adolescents [85]. In some cases, adolescents have attempted suicide due to failure to pass exams, especially in situations where a lot of emphasis is placed on excelling in school [84].

Violence or run-ins with law enforcement is also associated with suicidal behavior, especially in community studies although this is not necessarily consistent across clinical study patients [85]. The clinical population is a precise group of individuals and as such this may not be generalizable to the general population.

Adolescents who engaged in physical fights or bullying victimization were more likely to report suicidal behavior [90,95]. Experience of child abuse, sexual violence or harassment has been reported as a risk for suicide [84,91].

Suicidal behavior was also higher among adolescents who reported substance abuse, e.g., through the use of alcohol or illicit drugs or smoking cigarettes [88]. Internet addiction has also been associated with mental health issues and suicidal behavior, and it is also an avenue for cyber bullying [91].

On the other hand, the presence of support networks seems to be beneficial for adolescents. Adolescents who perceived their parents as understanding or supportive, and/or had helpful peers were less likely to report suicidal behavior

[90,91,95]. In this regard, the sense of belonging is likely to mitigate some negative emotions or feelings of worthlessness and rather improve one's self-esteem which are important factors for suicidal behavior.

Socio-demographic Risk Factors

Socio-demographic factors, such as being female are associated with suicide ideation, making plans and attempts [83,88–90,95]. However, the difference in the suicidal behavior has also been minimal between both sexes [84]. Furthermore, males (including adolescents) are at least five times more likely to die as a result of suicide compared to females which could be attributed to the lethal mechanisms that males are more likely to use [85]. Females are more likely to overdose on medication which can be effectively treated in hospitals as opposed to firearms and hanging that can be more fatal [85].

While older adolescents were more likely to report suicidal behavior [88], there have also been conflicting results [91]. Suicidal behavior is usually rare among younger children, and the rates tend to rise with an increase in age [86]. It is reported that mental health issues like depression tend to rise during the teenage years, and subsequently, suicidal behavior [91]. Nevertheless, a decrease in suicidal behavior with an increase in age could reflect better coping strategies or problem solving to challenges [91].

Adolescents from lower socio-economic backgrounds were also more likely to report suicidal behavior [88,90]. From the global school health surveys, adolescents who reported being hungry most of the time, which was an indication of poverty were more likely to report suicidal behavior [88].

Factors like religion and spirituality are considered to limit the incidence of suicidal attempts but not necessarily suicide ideation as they may be considered sins [91]. Suicide is sometimes considered a taboo which limits help-seeking behavior from individuals who need the services [91]. This could also potentially lead to under-reporting of the prevalence in some societies and regions [91].

Contextual Risk Factors

Contextual factors are likely to influence suicidal behavior. According to Durkheim, suicide is related to social integration, meaning strong integration in a community would reduce the risk for suicide [96,97]. This could be through religion or any kind of community where one feels a sense of belonging [97].

The economic situation in a region has an influence on suicidal behavior through psychological distress among individuals who may be unemployed or with insufficient employment opportunities [84]. In this regard, the GDP per capita and

the Gini coefficient are reflective of the economies at a national or regional level. The Gini coefficient measures the level of inequality in a country and can range from 0 to 1 or 0 to 100; with 1 or 100 representing the highest level of income inequality and 0 the lowest inequality [98]. There have been conflicting results on the association between suicidal behavior and the economic situation in a region. For instance, Carpena et al., found no association between suicidal thoughts and GDP nor the Gini coefficient in Brazil [99]. In contrast, Chen et al., found a positive association between suicide rates and the Gini coefficient in Japan and Europe but also an inverse association with the GDP per capita in the same mentioned country and region by varying age and gender [100]. Similar to other economic variables is the night light development index, which is designed to estimate the economic and human development in a local area, municipality or country [101]. The night light development index is a measure of the human development using the population density and nighttime satellite images [102]. The use of the night light development index is fairly recent as opposed to the GDP or the Gini coefficient. A study by Min et al., found it was associated with suicidal behaviors and depression in South Korea [101].

Civil strife or political instability could influence suicidal behaviors especially in situations where it contributes to mental health factors like increased stress, depression or anxiety [83]. However, lower rates of suicidal behavior have been associated with some cultures, religion or adequate support mechanisms within a society or family [83]. The feelings of support that stem from belonging to the supportive groups are beneficial for mental health and coping mechanisms during times of adversity. Thus, suicide and homicide rates could be related within a geographical location. Additionally, homicide and interpersonal violence may be related to the socioeconomic situation in an area [96]. There have been conflicting results on the correlation between suicide and homicide rates. For instance, the results have shown a weak insignificant relation, or a positive association e.g., in Europe, while the opposite was observed in Asia or the Americas [96].

Similarly, there have been conflicting results regarding the association between population density and suicide rates. Stark et al., found a positive association between suicide rates and the population density in Scotland [103]. In contrast, Knipe et al., found an inverse association in Sri Lanka [39].

The pupil to teacher ratio is an important factor that enables students to learn and is necessary when planning for education services, for instance, taking into consideration the attention each student would receive in the classroom or school premises from their respective teachers. In light of this, it is anticipated that the pupil to teacher ratios would be associated with the suicidal behavior of adolescents especially since it may influence how well they feel understood within the school

environment. Tan et al., found that the pupil to teacher ratio was associated with increased suicide ideation in China [104].

As a whole, suicidal behavior is relatively common among adolescents. However, to address mental health challenges, situational and contextual factors are important for effective and successful interventions and public health strategies.

2.5.6 The rationale for adolescents

Adolescence is an important phase in life in which people develop in various ways. Adolescents tend to go through psychological changes as they gradually grow into adulthood [91]. It is also a time when they develop an identity, learn to get autonomy or independence within a socio-cultural environment, experience biological and sexual changes and learn new cognitive skills [91,105,106]. Such changes in adolescents' lives may make them susceptible to experiencing stress [86]. It is also a time where communication is critical as adolescents are likely to confide with their peers rather than seek parental guidance on issues that influence their lives [106]. This is also exacerbated by a decline in the amount of time spent together and closeness between the parents and their adolescents [106]. Nonetheless, it is possible to have or develop a less volatile and understanding relationship between the adolescents and their parents depending on parenting skills [106].

The phase of adolescence also includes taking risks, challenging authorities or the moral structures of society, taking responsibility, building relationships and experimenting on various things like smoking, alcohol, sex, etc [105,106]. While adolescents may age out of some of the challenges they experience [106], it is also possible that they could develop into long term issues. Mental health issues like depression or anxiety tend to develop during adolescence and continue well into adulthood [106]. To effectively detect mental health issues or suicidal behavior among adolescents, stakeholders need to understand adolescent development [105]. This involves how to manage identity, privacy, confidentiality, and effective communication with the adolescents and their families [105]. Moreover, adolescents are sometimes faced with additional stress from pressures related to their academic performance, the ability to join tertiary institutions, and the possibility of unemployment [38]. Adolescents are also immensely affected by social media, which is associated with mental health issues and the possibility of bullying victimization [38]. Therefore, ensuring that this age group has adequate social support and access to mental health services is vital.

2.5.7 Prevention of suicide among adolescents

Prevention of suicidal behavior among adolescents is key in lowering the rate of suicide among this important age group. School programs can strengthen the areas that lower the odds of suicidal behavior, for example, through promoting connectedness within the school environments [83]. Another consideration is to address the risk factors for suicidal behavior through appropriate interventions, e.g., through reducing the occurrence of bullying victimization, substance abuse, physical fighting or violence [83]. The interventions could be universal, which target entire populations to create an environment where everyone is responsible for others, and thus creating a sense of safety and connectedness. Notwithstanding, the intervention may also be selective, where the individuals at risk of suicidal behavior are provided with support, for instance, anyone who may have depression or anxiety or experienced a traumatic event [83].

The interventions could also target adolescents who have admitted to having suicidal behavior, including previous attempts or those identified through screening programs; thus, this type of intervention is more personalized [83]. The screening interventions are done to identify adolescents with mental health or substance abuse issues [83]. According to Pelkonen et al., 1 – 8% of adolescent suicide victims had psychiatric disorders [86]. Within school environments, a suicide awareness curricula could also be implemented in a bid to reduce the stigma associated with suicide, encourage anyone to self-report suicidal behavior but also provide an opportunity for peer support in case students detect peers who may be in need of support [83]. However, this intervention has reportedly not been very effective and led to triggers or imitations for some students [83]. Thus, instead skills training and crisis interventions have been used as an intervention as they help with coping and alternative strategies for finding solutions to problems [83]. In general, a single intervention may not be effective to reduce the suicide rates but rather a combination of effects from various stakeholders, partners and interventions [83].

3 Aims

1) To determine the trends in the external causes of mortality from 1989 to 2018 in the Republic of Seychelles using the crude and age standardized mortality rates.

2) To ascertain the trends in the TBI related mortality over a 30-year period from 1989 to 2018 in Seychelles using the crude and age standardized mortality rates.

3) To estimate the prevalence of suicidal behavior among adolescents and identify the individual and contextual factors which might explain the variability in 53 low to middle income countries.

4 Materials and Methods

4.1 Study Population

There exists a paucity of data from the African region for decision making, including insufficient country coverage of civil registration systems. The Republic of Seychelles, a small island nation in the Indian Ocean off the east coast of Kenya, is an exception because all deaths are registered and medically certified [107,108]. It is one of the few countries in Africa where the civil registration and vital statistics system is comprehensive. Thus, the availability of this data makes it possible to conduct the research study. Furthermore, the scope of the data used in the study covers the entire country and population, with the population data updated every decade, for the last 30 years.

The adolescent age group is important and one of the largest globally. Therefore, it is worthwhile investing in this important age group and identifying challenges they may face, for example, mental health issues and implement interventions where necessary. The availability of data through cross-sectional surveys conducted in LMICs is a viable avenue through which adolescent behavior can be examined [109,110].

4.1.1 The Seychelles Mortality Data

The Republic of Seychelles lies 1 500 kilometers (932 mi) east of mainland East Africa and is a member of the African Union. With a population of 94 228 in 2016, 94 737 in 2017, and 98 462 in 2020 it has the smallest population of any African country [111].

The Civil Registration and Vital Statistics system in Seychelles has comprehensively covered the entire nation since 1989 and is regularly updated. Similarly, the census is regularly done every decade, thus the population data in the country is up to date [108].

The death certificates from the Civil Registration and Vital Statistics system were used in this study. There are several considerations which pertain to the use of the Seychelles mortality data. These considerations concern to the nature and use of death certificates for epidemiological studies. Such certificates show the “main cause

of death" and "underlying causes of death" and associated causes of death (hence four fields). For example, a pulmonary infection may appear as the "main cause of death" and "stroke" as an underlying cause of death, or the reverse. Yet in both cases, it is likely the "stroke" that was the main cause of death (and pulmonary infection represented a complication of stroke, which eventually killed the patient; but without a stroke the patient would not have had a pulmonary infection). The same can appear with, for example a "car crash" as cause A, and "brain hemorrhage". A brain hemorrhage from the trauma resulted in the death of the patient but it was secondary to the car crash. It could also be the case that the brain hemorrhage could have been spontaneous and not due to the trauma.

Generally, the persons who record the cause of death may not be too aware of these chains of causality (and mix causes A and B) and the secretary who enters the data in the electronic file may not wish to alter what a doctor has written (even if the sequence is clearly unlikely). Hence, when assessing trends of external causes (or other causes), it may be useful to consider diagnoses in any field (i.e., not only in "Cause A", but also in "Cause B", in "Cause C" and in "associated causes of death". This may result in some slight overestimate in mortality of some external causes, but only assessing diagnoses appearing in Cause A (as should be done if the database was fully certified, which is not the case for vital statistics from Seychelles) would clearly result in not including the considered diagnoses in a number of instances where they should be. Thus, all the four fields filled out in the death certificates were considered where available. If any external cause of mortality or injury contributing to death was mentioned in a death certificate, the case was included as part of the injury deaths.

The cases included in **Study I** and **Study II** were selected from the Seychelles Mortality Database. The WHO International Classification of Diseases 10th revision (ICD – 10) was used to identify and categorize the cases. The main categories used in both studies included drowning, road traffic crashes, suicide, homicide, poisoning, fire-related burns, other unintentional injuries, and external causes with undetermined intent. The cases where the cause of injury could not be explicitly placed within the above first six mentioned categories were included in the other unintentional category: for example, electrocution, shark attacks and rock accidents among others. While the cases included in the undetermined category were cases where an injury was mentioned as a cause of death, but the cause of the injury was not mentioned, for example, skull fractures, head injuries, etc. The cases were identified and reviewed by AA and MLW.

In **Study II**, a case was considered if a traumatic brain injury directly contributed to death as a result of an injury, for example, injuries sustained in a car crash. The cases were identified by AA, and reviewed by JPP, an experienced neurosurgeon/neurotraumatologist.

4.1.2 The Global School Health Survey (GSHS) Data

Moreover, suicide, which is one aspect of external causes of mortality is usually under-reported owing to the stigma surrounding mental health in general. Suicide is also considered criminal in some countries which often leads to gaps in data that are made available for research. Therefore, data on suicide is often limited, and where available is often masked and lumped within other causes, such as poisoning. In order to add to knowledge on suicidal behavior in LMICs, data available from the Global School Health Surveys (GSHS) conducted among school attending adolescents [109,110] was used to identify the prevalence and contextual factors.

The GSHS is a cross-sectional survey carried out among adolescents in schools in 94 LMICs. The data are collected from nationally representative samples of school-going adolescents typically aged 13 – 17 years. A two-stage cluster sample design was used to collect these data. Schools were selected with a probability proportional to their respective enrollment sizes. Classrooms within schools were randomly selected and all students were eligible to participate in the research through responding to the questionnaires. The students who participated in the survey made self-reported responses. A standard questionnaire was used in all countries where the study was conducted; however, each country could modify which questions to omit or add within their respective ministries. The recall period for the questions asked was twelve months preceding the survey. The survey data are freely and publicly available. A description of the survey and methodology is available elsewhere [109,110]. All countries that collected all the necessary information on suicidal behavior were included in the analysis.

A total of fifty-three countries that had surveys conducted between 2009 and 2016 were included in the analysis to estimate the prevalence of suicidal behavior. The following regions were represented in the study: seven countries from Africa, fifteen countries from the Americas, ten countries from the East Mediterranean, five countries from South East Asia, and sixteen countries from the West Pacific regions. On the other hand, only thirty-three countries had information on all the contextual risk factors of interest, were subsequently included in the multilevel analysis.

Variables used in the analysis

Three dependent variables were considered in **Study III**; suicide ideation, made a suicide plan and attempted suicide. The fixed individual variables included age, sex, going hungry during the past 30 days (considered as a measure of socio-economic status at the family level), getting physically attacked, involvement in physical fights, being seriously injured, bullying victimization, loneliness, feelings of anxiety through being so worried about something that it affected ones sleep, truancy through missing school without permission, availability of helpful peers at school,

availability of close friends, having understanding parents or guardians and the use of alcohol and/or smoking cigarettes.

The country level variables included the Gini Coefficient (GC), the Gross Domestic Product (GDP) per capita, the pupil-to-teacher ratio, the population density, the intentional homicide rate, the legal situation of suicide in a country and the Night Light Development Index. The country level variable estimates were downloaded from the United Nations and World Bank websites [102,111,112].

4.2 Statistical Analysis

The annual population for each year, over a period of 30 years (1989 to 2018) was used. Based on this, the age standardized mortality rates were estimated and standardized according to the World Health Organization standard population in **Study I** and **Study II**. The WHO standard population allows for comparisons to be made at a global level or with other countries [113]. Poisson regression was used to estimate the annual trends in **Study I and II**; however, where over-dispersion of data was observed, negative binomial regression models were used instead.

In **Study III**, the data analysis was restricted to adolescents who were aged 12 to 16 years. The age restriction was done since the study participants' age was inconsistent across various countries. The datasets used for the analysis were from 2009 to 2016, in order to use the most recent datasets from the various respective countries.

For the suicidal behavior prevalence estimates, the survey design of the dataset was considered. A two-level multivariable multilevel mixed effects logistic regression model was used to determine the association between suicidal behavior and the risk factors among the adolescents. The model included individual level, and country level covariates, as well as random country level intercepts. The Hox 2010 bottom-up approach was used to fit the model [114]. The models for suicide ideation, made a suicide plan and attempted suicide were done separately.

The following steps were used in developing the multilevel multivariable model: An intercept only model for suicide ideation, made a suicide plan and attempting suicide was first fitted. Next, at the fixed level, individual level and country level explanatory factors were added to the model. The individual level variables that were statistically significant were retained in the model, while the country level variables were retained regardless of statistical significance. The random country level intercept was added to the previous model. Thereafter, the country level variables were added one by one to the previous model at the random effects level. Interactions between the significant country level factors and the individual variables were tested and retained if significant. Collinearity was found in the regional models but not when all regions with their respective countries were pooled. Thus, for regional

models, the night light index variable was not included for Africa, while the availability of the suicide law was not included for the Americas. Additionally, in the East Mediterranean model, the pupil to teacher ratio, the homicide rate, population density and the suicide law were not included. Finally, the population density, suicide law and the night light index were not included for South East Asia.

The Bayesian Information Criterion (BIC) was used to test for the fit of the model, while the Gauss-Hermite adaptive quadrature method was used for the mixed effects model parameters.

The level of statistical significance used was $p<0.05$ with a 95% confidence interval. The data analysis was conducted using Stata version 17 (StataCorp, TX, USA).

4.3 Ethical Considerations

Studies I and II used data from the Seychelles Mortality Database which was de-identified with no identified characteristics mentioned and available in an aggregated form. Thus, there were no threats to the privacy of persons in the database or their surviving relatives. No individuals with relations to those appearing in the database were contacted during the research period. The researchers with official permissions to the data signed a non-disclosure and data confidentiality agreement to access the data.

Study III used data that was downloaded from the CDC website. The data was stripped of identifying characteristics. Each respective ministry and government approved of the study prior to data collection. Furthermore, each respective country had an Institutional Review Board that approved the study, and guardians or parents to the adolescents gave permission for their children to participate in the survey. Each adolescent voluntarily participated in the study.

Therefore, the availability of such data from the Seychelles, within African region represents a valuable opportunity to understand trends in mortality due to external causes. The data from the GSHS surveys provides evidence-based research on the prevalence of suicidal behavior among adolescents in LMICs.

5 Results

5.1 External Causes of Mortality

From 1989 to 2018, a total of 18 961 deaths from all causes occurred in the Republic of Seychelles. By sex, 57.4% of deaths recorded were among males. By age group, there was a significantly higher mortality among the under 1 age group compared to the 1 – 9 age group. The proportion increased with an increase in age, peaking at 28.5% among those aged 80 years and above. Overall, the mean age of the population included in the all-cause death register was 64.7 years (SD 22.2); with 69.9 (SD=22.4) for females and 60.8 (SD=21.3) for the males, with the maximum age being 119 years. (Table 2).

Injuries accounted for 8.5% of deaths during the 30-year period of the study. The data revealed that 78.3% of the injury mortality occurred among males. Among the external causes of mortality, drowning was the leading cause at 21.8%, followed by road traffic injuries at 17.5%, other unintentional injuries at 17.3%, and the injuries of undetermined intent at 12.7%. By sex, drowning was the most frequent cause of death among males at 24.5% while other unintentional injuries contributed to the highest mortality among females at 37.0%.

Males were at least twice as likely to die from all injuries compared to females, after adjusting for age (RR 2.16; 95% CI 1.82, 2.56) as shown in Table 3. Males were 17 times more likely to die from suicide compared to females (RR 17.13; 95% CI 5.63, 52.06). However, males were less likely to die from other unintentional injuries although it was not statistically significant (RR 0.88; 95% CI 0.61, 1.26).

Table 2: Summary Statistics for External Causes of Mortality.

Categories	Mean	SD	Median	IQR	Number (%)
Both Sexes					
Drowning	42.4	19.1	41.5	29.5, 57.0	352 (21.8)
Road traffic injuries	34.6	19.0	31.0	21.0, 47.0	282 (17.5)
Suicide	41.6	15.7	38.0	31.0, 50.0	139 (8.6)
Homicide	35.1	13.9	32.0	25.5, 42.0	116 (7.2)
Poisoning	37.7	14.9	36.0	27.0, 45.0	121 (7.5)
Falls	50.6	20.2	51.0	36.5, 63.0	64 (4.0)
Fire related burns	42.9	23.6	41.5	24.0, 60.0	54 (3.3)
Other unintentional injuries	63.3	26.5	73.0	41.0, 85.0	280 (17.4)
Undetermined intent	46.3	19.9	45.0	29.5, 60.0	204 (12.7)
All injury cases	44.5	22.2	41.0	28.0, 60.0	1612 (8.5*)
All causes	64.7	22.2	70.0	53.0, 81.0	18961
Males					
Drowning	43.0	18.8	42.0	31.0, 57.0	310 (24.5)
Road traffic injuries	33.9	17.9	30.0	21.0, 45.0	225 (17.8)
Suicide	41.9	15.8	39.0	31.0, 50.0	129 (10.2)
Homicide	34.6	12.7	32.0	26.0, 40.0	89 (7.1)
Poisoning	38.3	14.6	36.0	28.0, 45.0	89 (7.1)
Falls	49.5	17.7	51.0	37.0, 60.0	56 (4.4)
Fire related burns	43.4	22.2	42.5	25.0, 57.0	42 (3.3)
Other unintentional injuries	52.5	24.9	50.0	33.0, 75.0	151 (12.0)
Undetermined intent	45.3	18.1	44.0	29.5, 58.0	172 (13.6)
All injury cases	42.1	19.4	40.0	27.0, 55.0	1263 (11.6*)
All causes	60.8	21.3	65.0	49.0, 77.0	10889 (47.4)
Females					
Drowning	38.1	21.1	38.5	26.0, 54.0	42 (12.0)
Road traffic injuries	37.1	22.9	33.0	20.0, 54.0	57 (16.3)
Suicide	37.8	13.8	37.5	30.0, 45.0	10 (2.9)
Homicide	36.8	17.6	33.0	24.0, 46.0	27 (7.7)
Poisoning	35.9	15.9	35.0	23.5, 41.5	32 (9.2)
Falls	58.4	34.0	66.5	30.0, 87.5	8 (2.3)
Fire related burns	41.3	29.1	29.5	21.5, 65.0	12 (3.4)
Other unintentional injuries	75.9	22.6	83.0	72.0, 90.0	129 (37.0)
Undetermined intent	51.8	27.2	52.0	28.0, 74.5	32 (9.2)
All injury cases	53.4	28.5	54.0	28.0, 81.0	349 (4.3*)
All causes	69.9	22.4	76.0	62.0, 85.0	8072 (42.6)

*SD = Standard Deviation; IQR = Interquartile Range; *Percent of injuries out of all causes*

By broad age categories, mortality for all external causes of mortality was highest among the 20-39 and 40-59 age groups with the age standardized rate of 36.8 and 31.2 per 100 000 person-years for males, respectively. The same was observed for drowning at a standardized mortality rate of 8.2 per 100 000 for the 40-59 age group and 8.1 per 100 000 person-years from road traffic injuries for the male age groups. While for females, the highest injury mortality was in the 60 years and older age group at 12.1 per 100 000 female person-years. The other unintentional injuries category was the leading cause among the older females (60+) at 8.3 per 100 000 female person-years.

Over the 30-year period, the injury mortality rate declined by 0.1% (95% CI -1,1, 0.8%) annually among males but increased by 0.5% (95% CI -1.4, 2.4%) among

the females. Among the age groups, the highest decrease was recorded among the 0 – 19-year-olds in both the males and females at 2.5% (95% CI -6.5, 1.7%) and 3.2% (95% CI -9.7, 3.8%) respectively. Overall, drowning declined by 0.02% (95% CI -1.9, 1.9%) among males, although it increased by 2.3% (95% CI -3.4, 8.3%) among females. On the other hand, road traffic injury mortality increased by 2.7% (95% CI 0.1, 5.2%) and 0.1% (95% CI -5.1, 5.7%) annually among males and females respectively. Notable declines were observed for external causes with undetermined intent at 4.5% (95% CI -6.9, -2.0%) and 2.3% (95% CI -7.9, 3.6%) among males and females respectively during the 30-year period. The other unintentional injuries reduced by 1.1% (95% CI -3.7, 1.5%) among males and increased by 0.4% (95% CI -2.6, 3.6%) among females annually. A presentation of the trend of the age standardized mortality rates from external causes by category is in Figure 2.

Table 3: Rate Ratios of External Causes of Mortality.

Category	Rate Ratios (Ref: Females)			Rate ratios (Adjusted for age)		
	RR	**95% CI**	**p-value**	**RR**	**95% CI**	**p-value**
Drowning	7.38	5.34, 10.18	<0.001	7.77	5.63, 10.73	<0.001
Road traffic injuries	3.31	2.25, 4.87	<0.001	2.25	1.43, 3.53	<0.001
Suicide	16.76	6.72, 41.84	<0.001	17.13	5.63, 52.06	<0.001
Homicide	2.70	1.51, 4.83	0.001	1.61	0.79, 3.28	0.192
Poisoning	2.24	1.29, 3.89	0.004	1.70	0.87, 3.33	0.124
Falls	6.63	2.54, 17.29	<0.001	5.01	1.83, 13.71	0.002
Fire related burns	2.89	1.22, 6.83	0.016	2.58	1.01, 6.63	0.048
Other unintentional injuries	0.88	0.63, 1.24	0.472	0.87	0.61, 1.25	0.465
Undetermined intent	4.76	2.91, 7.77	<0.001	3.60	2.15, 6.04	<0.001
All injuries						
All injury cases	3.00	2.56, 3.51	<0.001	2.16	1.82, 2.56	<0.001
By age groups						
0-19 (ref)	1			1		
20-39	2.72	2.01, 3.67	<0.001	2.47*	1.82, 3.34	<0.001
40-59	0.85	0.64, 1.12	0.25	0.76*	0.57, 1.01	0.06
60+	0.25	0.19, 0.32	<0.001	0.26*	0.20, 0.35	<0.001

**Adjusted for sex*
RR = Rate Ratios

5.2 Traumatic Brain Injuries

TBIs contributed to 1.7% (n=327) of the overall mortality from 1989 to 2018. Males were over-represented at 84.4% (n=278). TBI-related mortality occurred in 20.3% of the injury cases recorded. Skull fractures combined with intracranial injury was the most frequent TBI recorded at 50.8%. By the cause of injury, road traffic collisions contributed to the highest TBI-associated mortality at 48.0%.

The overall TBI mortality rate was 22.6 and 4.0 per 100 000 person-years among males and females respectively over 30 years (Table 4). During the 10-year intervals from 1989/1998, 1999/2008, 2009/2018, the TBI- standardized mortality rates were 27.7, 22.3 and 20.1 (p=0.346) among males and 3.0, 3.9 and 4.6 (p=0.243) among females respectively. There was no statistically significant decline in the trend over time for the three 10-year periods. During the 10-year periods, the highest rates varied between the 20-39 and the 40-59-year age groups among males; and also varied between the 0-19 and 60 years plus among the females (Table 5).

The age-standardized fall-related TBI mortality rates during the 30-year period were 2.8 and 0.2 per 100 000 person-years among males and females respectively. From 1989/1998, 1999/2008, and 2009/2018, the rates among males were 2.0, 3.3 and 3.1 (p=0.066) per 100 000 person-years, while no TBI-related death due to falls were reported from 2009/2018 among females. The highest rate among males was in the 40-59 age group at 1.2, while the 0-19 and 20-39 age groups each had rates of 0.1 among the females during the entire study period. There were no TBI related falls recorded among females 40 years and older.

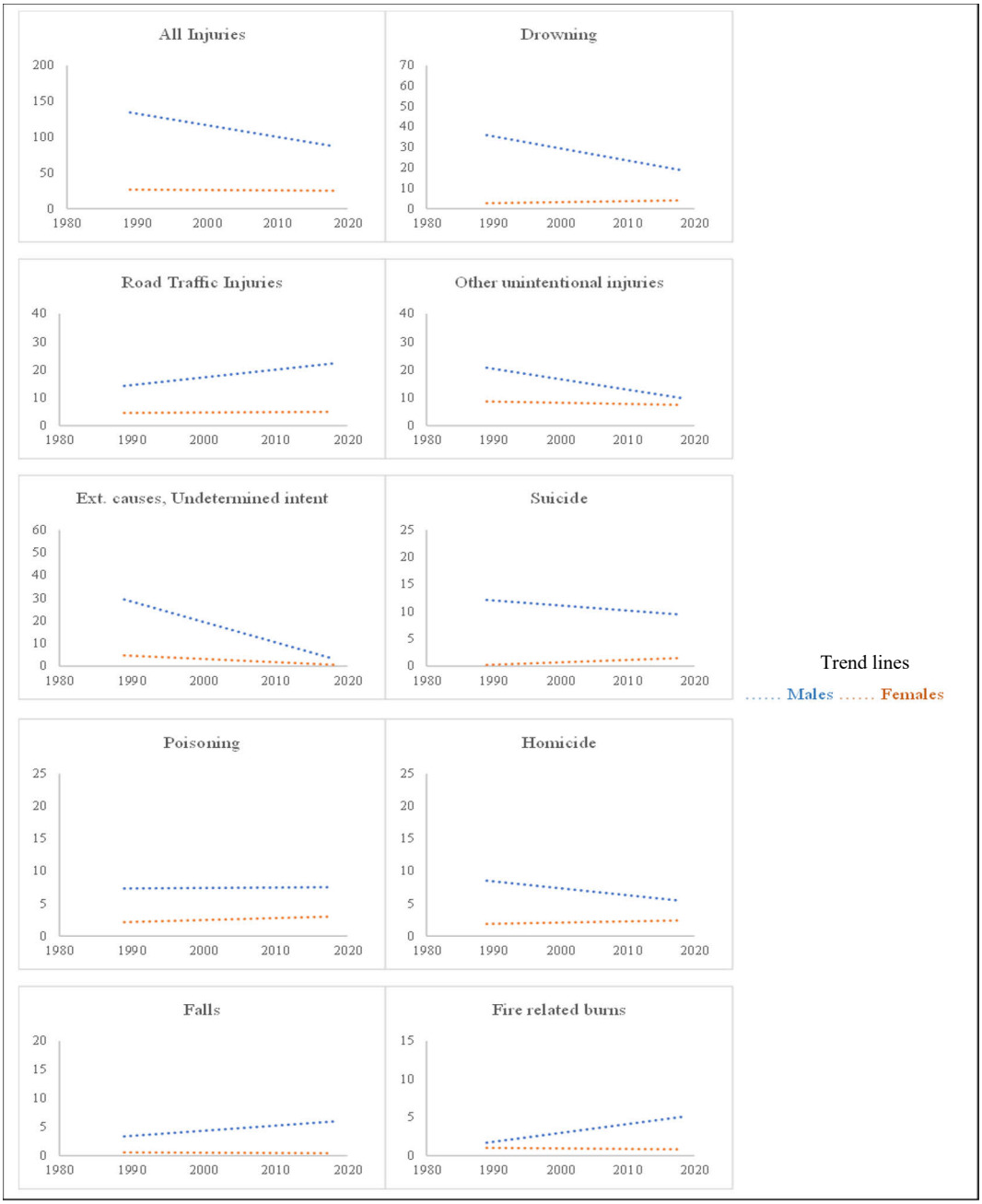


Figure 13: Trends of age standardized mortality rates for external causes (Seychelles).

TBI mortality related to drowning, suicide, homicide and other unintentional injuries combined had an age standardized rate of 2.6 and 0.3 per 100 000 person-years among males and females respectively during the 30-year period. From 1989/1998,

1999/2008, and 2009/2018, the rates among males were 2.7, 3.6 and 1.8 (p=0.618) per 100 000 person-years, while no TBI related deaths were reported from 1989 to 1998 among females.

Regarding the external causes with undetermined intent, the TBI-related age-standardized rate was 7.1 and 0.8 per 100 000 person-years among males and females respectively during the entire study period. From 1989/1998, 1999/2008, 2009/2018, the rates among males and females were 13.1, 6.1, 4.7 (p=0.003) and 0.8, 0.5, 1.0 (p=0.446) per 100 000 person-years respectively, suggesting a decline among males. External causes of undetermined intent were the leading cause of TBI related mortality within the first decade 1989/1998 among males. The highest rates from external causes with undetermined intent were 3.1 for the age group 40 – 59 years among males and 0.4 for the 60 years and older age group among females.

Table 4: TBI age standardized mortality rates for the top four categories.

	Males				Females			
	Crude rates	**Stan. rates**	**95% CI**	**Trend p-value**	**Crude rates**	**Stan. rates**	**95% CI**	**Trend p-value**
All TBIs								
Thirty years				0.160				0.455
1989-2018	22.4	22.6	19.9, 25.2		4.0	4.0	2.9, 5.1	
Fifteen-year intervals				0.247				0.338
1989-2003	24.2	26.3	21.8, 30.9		3.3	3.3	1.8, 4.7	
2004-2018	20.8	20.0	16.7, 23.4		4.7	4.6	3.0, 6.3	
Ten-year intervals				0.346				0.243
1989-1998	24.5	27.7	21.7, 33.6		3.0	3.0	1.2, 4.9	
1999-2008	22.1	22.3	17.7, 27.0		4.1	3.9	2.0, 5.7	
2009-2018	20.9	20.1	16.0, 24.2		4.8	4.6	2.6, 6.6	
Road Traffic Injury TBIs								
Thirty years				0.796				0.542
1989-2018	10.1	10.0	8.2, 11.8		2.7	2.7	1.8, 3.6	
Fifteen-year intervals				0.781				0.537
1989-2003	9.9	9.9	7.3, 12.6		2.3	2.3	1.0, 3.6	
2004-2018	10.3	10.0	7.6, 12.4		3.0	3.1	1.7, 4.4	
Ten-year intervals				0.732				0.373
1989-1998	9.9	10.0	6.6, 13.3		1.9	2.1	0.5, 3.6	
1999-2008	9.9	9.4	6.5, 12.3		2.9	2.8	1.2, 4.4	
2009-2018	10.5	10.5	7.5, 13.6		3.1	3.1	1.4, 4.8	
Fall TBIs								
Thirty years				0.065				0.737
1989-2018	2.7	2.8	1.8, 3.8		0.2	0.2	<0.1, 0.4	
Fifteen-year intervals				0.012				0.882
1989-2003	1.4	1.7	0.5, 2.9		0.2	0.2	<0.1, 0.5	
2004-2018	3.7	3.5	2.1, 4.9		0.2	0.1	<0.1, 0.4	
Ten-year intervals				0.066				0.307
1989-1998	1.4	2.0	0.2, 3.7		0.3	0.2	<0.1, 0.7	
1999-2008	2.9	3.3	1.4, 5.2		0.5	0.5	<0.1, 1.2	
2009-2018	3.5	3.1	1.5, 4.6		0.0	0.0	0.0, 0.0	

	Males				Females			
	Crude rates	**Stan. rates**	**95% CI**	**Trend p-value**	**Crude rates**	**Stan. rates**	**95% CI**	**Trend p-value**
***Others**								
Thirty years				0.193				0.386
1989-2018	2.7	2.6	1.7, 3.5		0.3	0.3	<0.1, 0.6	
Fifteen-year intervals				0.326				0.428
1989-2003	3.2	3.5	1.8, 5.1		0.2	0.1	<0.1, 0.4	
2004-2018	2.2	2.0	1.0, 3.1		0.5	0.5	<0.1, 1.1	
Ten-year intervals				0.618				0.308
1989-1998	2.5	2.7	0.9, 4.5		0.0	0.0	0.0, 0.0	
1999-2008	3.6	3.6	1.7, 5.4		0.5	0.4	<0.1, 1.0	
2009-2018	2.0	1.8	0.6, 2.9		0.4	0.5	<0.1, 1.1	
External causes, Undetermined intent TBIs								
Thirty years				0.002				0.747
1989-2018	6.9	7.1	5.6, 8.6		0.9	0.8	0.3, 1.3	
Fifteen-year intervals				0.001				0.577
1989-2003	9.7	11.2	8.2, 14.3		0.7	0.7	<0.1, 1.3	
2004-2018	4.6	4.4	2.8, 6.0		1.1	0.9	0.2, 1.6	
Ten-year intervals				0.003				0.446
1989-1998	10.7	13.1	8.8, 17.3		0.8	0.8	<0.1, 1.6	
1999-2008	5.8	6.1	3.6, 8.6		0.5	0.5	<0.1, 1.1	
2009-2018	5.0	4.7	2.8, 6.7		1.3	1.0	0.2, 1.9	

Stan. Rates = age standardized mortality rates

CI = Confidence Intervals

**Others includes TBI related mortality due to drowning, suicide, homicide, fire-related burns, and other unintentional injuries*

Table 5: Age standardized TBI mortality rates by age group for the top four categories.

Age group	Males				Females			
	All years (1989–2018)	1989–1998	1999–2008	2009–2018	All years (1989–2018)	1989–1998	1999–2008	2009–2018
All TBIs								
0–19	3.4	4.1	3.2	2.9	1.4	1.4	1.8	1.1
20–39	8.0	8.3	8.5	7.3	1.0	0.3	1.5	1.3
40–59	7.4	9.2	7.1	6.8	0.8	0.8	0.5	0.9
60+	3.7	5.9	3.4	2.6	0.8	0.6	0.2	1.5
Road Traffic Injury TBIs								
0–19	2.6	3.2	1.9	2.7	0.9	0.7	1.3	0.8
20–39	4.2	3.4	5.4	3.7	0.8	0.3	1.1	0.9
40–59	2.2	2.0	1.5	2.8	0.6	0.8	0.5	0.5
60+	0.8	1.3	0.3	1.0	0.4	0.3	0.0	0.7
External Causes, Undetermined Intent TBIs								
0–19	0.4	0.7	0.2	0.3	0.3	0.5	0.3	0.3
20–39	2.0	3.4	1.4	1.2	0.1	0.0	0.2	0.0
40–59	3.1	6.0	3.0	1.9	0.1	0.0	0.0	0.2
60+	1.7	2.9	1.4	1.2	0.4	0.3	0.0	0.7
Fall TBIs								
0–19	0.2	0.0	0.7	0.0	0.1	0.2	0.0	0.0
20–39	0.7	0.2	0.2	1.5	0.1	0.0	0.2	0.0
40–59	1.2	0.8	1.3	1.4	0.0	0.0	0.0	0.0
60+	0.6	0.8	1.0	0.2	0.0	0.0	0.0	0.0
***Others**								
0–19	0.2	0.2	0.2	0.0	0.1	0.0	0.3	0.0
20–39	1.2	1.2	1.4	0.8	0.1	0.0	0.0	0.2
40–59	0.8	0.4	1.3	0.7	0.1	0.0	0.0	0.2
60+	0.5	0.8	0.7	0.2	0.1	0.0	0.2	0.0
External Causes, Undetermined Intent TBIs								
0–19	0.4	0.7	0.2	0.3	0.3	0.5	0.3	0.3
20–39	2.0	3.4	1.4	1.2	0.1	0.0	0.2	0.0
40–59	3.1	6.0	3.0	1.9	0.1	0.0	0.0	0.2
60+	1.7	2.9	1.4	1.2	0.4	0.3	0.0	0.7

**Others includes TBI related mortality due to drowning, suicide, homicide, fire-related burns, and other unintentional injuries*

5.3 Suicidal Behavior among Adolescents

The risk factors for suicidal behavior are presented by region. A total of 33 countries were included in the multilevel analysis: seven countries from Africa, eight from the Americas, three from the East Mediterranean, five from South East Asia and ten from the Western Pacific regions.

5.3.1 Suicide Ideation

Feeling lonely was consistently the strongest risk factor for suicide ideation in each of the regions. Adolescents who were feeling worried and anxious were twice as likely to consider suicide in Africa, the Americas, South East Asia and the Western Pacific, but 74% more likely in the East Mediterranean region. Adolescents who perceived their parents as understanding and supportive were less likely to consider suicide in the Americas, East Mediterranean, South East Asia, the Western Pacific but it was not statistically significant in the African region. The presence of helpful peers at school reduced the odds of suicide ideation in the Americas, East Mediterranean and Western Pacific regions, however this was not statistically significant in Africa and South East Asia.

Among the contextual variables, adolescents in countries from Africa and South East Asia were more likely to think about suicide with every unit increase in the Gini coefficients but the reverse was observed in the Americas. However, GDP per capita in the Americas and South East Asia was associated with lower odds of suicide ideation, although the opposite was noted in Africa. The pupil to teacher ratio was positively associated with suicide ideation in the Americas but a negative association was noted in South East Asia. Adolescents from South East Asian countries were twice as likely to think about suicide per unit increase in the homicide rates, while lower odds were observed in Africa. Adolescents from Africa and the Americas were less likely to contemplate suicide per unit increase in the population densities. African adolescents were 26% more likely to consider suicide if suicide was punishable by law. The night light development index was not associated with suicide ideation in any of the regions. The odds are presented in Table 6.

Table 6: Mixed effects logistic regression model estimates (Suicide ideation).

Variables	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
	AFRICA		AMERICAS		EAST MEDITERRANEAN		SOUTH EAST ASIA		WESTERN PACIFIC	
Age (continuous)	1.04	0.99, 1.09	1.04	1.01, 1.08	1.20	1.11, 1.28	1.07	1.02, 1.12	1.06	1.03, 1.10
Sex (Ref: Male)	1.26	1.12, 1.41	2.49	2.31, 2.67	1.82	1.50, 2.21	1.53	1.35, 1.73	1.74	1.61, 1.89
Went hungry	1.21	1.01, 1.45	1.07	0.91, 1.26	1.10	0.81, 1.47	1.53	1.23, 1.91	1.06	0.92, 1.22
Attacked	1.20	1.05, 1.36	1.56	1.45, 1.69	1.27	1.05, 1.54	1.12	0.98, 1.28	1.41	1.29, 1.54
Physical fighting	1.15	1.00, 1.31	1.30	1.21, 1.40	1.27	1.05, 1.55	1.04	0.90, 1.20	1.26	1.15, 1.37
Injured	1.25	1.11, 1.42	1.20	1.12, 1.29	1.66	1.39, 1.98	1.36	1.19, 1.56	1.49	1.37, 1.62
Bullying victimization	1.30	1.15, 1.48	1.56	1.45, 1.68	1.58	1.30, 1.91	1.81	1.58, 2.06	1.66	1.52, 1.81
Loneliness	2.14	1.83, 2.49	3.52	3.22, 3.85	2.19	1.77, 2.70	2.77	2.34, 3.27	2.33	2.11, 2.58
Anxiety	2.08	1.78, 2.44	2.65	2.40, 2.92	1.74	1.39, 2.18	2.24	1.85, 2.71	2.04	1.81, 2.29
No close friends	1.53	1.27, 1.84	1.50	1.31, 1.71	1.75	1.29, 2.36	1.89	1.49, 2.40	1.56	1.34, 1.81
Truancy	1.20	1.06, 1.37	1.32	1.23, 1.41	1.25	1.04, 1.50	1.28	1.12, 1.46	1.16	1.06, 1.26
Helpful peers	0.94	0.82, 1.06	0.88	0.82, 0.94	0.73	0.61, 0.88	0.92	0.81, 1.04	0.84	0.77, 0.91
Supportive parents or guardians	0.90	0.80, 1.02	0.61	0.56, 0.65	0.71	0.59, 0.86	0.74	0.65, 0.85	0.60	0.55, 0.66
Alcohol/smoke cigarettes	1.79	1.56, 2.05	2.12	1.97, 2.28	1.93	1.51, 2.48	1.82	1.54, 2.14	1.81	1.65, 1.98
Gini coefficient	1.01	1.00, 1.02	0.97	0.96, 0.98	0.95	0.90, 1.01	1.15	1.02, 1.30	1.02	0.90, 1.15
GDP per capita	1.06	1.01, 1.10	0.96	0.93, 0.99	0.90	0.80, 1.03	0.67	0.55, 0.81	1.01	0.82, 1.25
Pupil to teacher ratio	0.99	0.97, 1.00	1.03	1.01, 1.05	NA		0.94	0.92, 0.95	1.04	0.95, 1.15
Homicide	0.96	0.92, 0.99	1.00	1.00, 1.01	NA		2.05	1.46, 2.87	1.04	0.89, 1.21
Population density	0.56	0.39, 0.81	0.84	0.75, 0.93	NA		NA		0.70	0.39, 1.26
Suicide law	1.26	1.03, 1.55	NA		NA		NA		NA	
Night light index	NA		0.47	0.06, 3.80	NA		NA		NA	

OR is Odds Ratio; CI is Confidence Interval

5.3.2 Made a Suicide Plan

The risk factors for making a suicide plan also slightly varied by region. Loneliness was one of the strongest individual risk factors in all the regions: however, it was the strongest in the Americas and East Mediterranean. The strongest risk factor in other regions was a lack of close friends in South East Asia and Western Pacific; and feeling worried and anxious in Africa. Adolescents with understanding and supportive parents or guardians were less likely to make a suicide plan in all the 4 regions, but it was non-significant in Africa. Additionally, the presence of helpful peers at school was associated with lower odds of making suicide plans in the Americas and East Mediterranean regions but it was non-significant in the other regions.

Except for Africa, where the Gini coefficient was positively associated with making a suicide plan, a negative association was observed in the Americas and East Mediterranean, and no association in South East Asia and Western Pacific. Regarding the GDP per capita, lower odds of making a suicide plan were observed in the Americas, East Mediterranean and South East Asia but non-significant in Africa and the Western Pacific regions. Students were less likely to have made a suicide plan with a per unit increase in the pupil to teacher ratio in the African and South East Asian regions. Regarding homicide rates, suicide planning was associated with higher odds in the Americas and South East Asian countries, while lower odds were observed in Africa. Furthermore, higher population densities were associated with lower odds of making suicide plans in the African and Americas regions. The suicide law was not associated with making suicide plans in any region. Adolescents in the Americas were less likely to make a suicide plan with a per unit increase in the night light development index. The estimates are presented in Table 7.

Table 7: Mixed effects logistic regression model estimates (Suicide planning).

Variables	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
	AFRICA		AMERICAS		EAST MEDITERRANEAN		SOUTH EAST ASIA		WESTERN PACIFIC	
Age (continuous)	1.03	0.98, 1.08	1.03	1.00, 1.06	1.21	1.13, 1.30	0.99	0.95, 1.04	1.05	1.01, 1.09
Sex (Ref: Male)	1.14	1.01, 1.28	2.22	2.06, 2.39	1.64	1.34, 2.00	1.31	1.16, 1.47	1.44	1.32, 1.56
Went hungry	1.09	0.91, 1.30	1.04	0.88, 1.23	1.19	0.88, 1.61	1.28	1.03, 1.60	1.09	0.95, 1.26
Attacked	1.22	1.08, 1.39	1.49	1.38, 1.62	1.35	1.11, 1.65	1.11	0.98, 1.26	1.37	1.25, 1.50
Physical fighting	1.21	1.06, 1.38	1.35	1.25, 1.45	1.06	0.86, 1.31	1.13	0.99, 1.29	1.27	1.16, 1.39
Injured	1.30	1.15, 1.47	1.26	1.17, 1.35	1.37	1.14, 1.66	1.16	1.02, 1.31	1.43	1.31, 1.56
Bullying victimization	1.33	1.18, 1.51	1.44	1.33, 1.55	1.52	1.23, 1.86	1.39	1.22, 1.58	1.55	1.42, 1.70
Loneliness	1.73	1.48, 2.02	2.71	2.48, 2.97	2.13	1.71, 2.66	2.55	2.16, 3.01	2.02	1.82, 2.24
Anxiety	1.96	1.67, 2.30	2.27	2.05, 2.51	1.37	1.08, 1.75	1.94	1.60, 2.35	1.94	1.72, 2.19
No close friends	1.77	1.48, 2.12	1.91	1.67, 2.17	2.05	1.52, 2.77	2.65	2.14, 3.27	2.17	1.88, 2.50
Truancy	1.25	1.10, 1.42	1.25	1.16, 1.34	1.32	1.09, 1.60	1.32	1.16, 1.49	1.26	1.16, 1.38
Helpful peers	1.05	0.93, 1.20	0.93	0.87, 1.00	0.75	0.62, 0.91	0.93	0.83,1.05	0.93	0.85, 1.01
Supportive parents or guardians	0.92	0.82, 1.04	0.65	0.61, 0.70	0.74	0.60, 0.90	0.77	0.68, 0.87	0.73	0.67, 0.81
Alcohol/smoke cigarettes	1.42	1.24, 1.62	2.06	1.91, 2.23	1.49	1.14, 1.96	1.74	1.49, 2.04	1.75	1.59, 1.93
Gini coefficient	1.04	1.03, 1.05	0.95	0.94, 0.97	0.92	0.87, 0.97	1.07	0.951.20	1.02	0.93, 1.13
GDP per capita	1.00	0.95, 1.04	0.94	0.91, 0.97	0.82	0.72, 0.94	0.75	0.63, 0.89	0.95	0.81, 1.12
Pupil to teacher ratio	0.96	0.94, 0.97	1.01	0.98, 1.03	NA		0.94	0.93, 0.95	1.02	0.95, 1.10
Homicide	0.92	0.89, 0.96	1.01	1.01, 1.02	NA		1.76	1.29, 2.41	1.05	0.93, 1.19
Population density	0.61	0.43, 0.86	0.73	0.65, 0.82	NA		NA		0.71	0.45, 1.12
Suicide law	0.96	0.77, 1.19	NA		NA		NA		NA	
Night light index	NA		0.11	0.01, 0.98	NA		NA		NA	

OR is Odds Ratio; CI is Confidence Interval

5.3.3 Attempted Suicide

The strongest individual risk factor by region was a lack of close friends in the South East Asian and Western Pacific regions, loneliness in the Americas, feeling worried and anxious in Africa and the use of alcohol and/or smoking cigarettes in the East Mediterranean region. Congruently, adolescents with understanding parents or guardians were less likely to report attempting suicide in all regions, except Africa where no association was observed. The presence of helpful peers at school was also associated with lower odds of suicide attempts in the Americas, East Mediterranean and Western Pacific regions.

Regarding the contextual variables, the Gini coefficient was positively associated with suicide attempts in the African and the Western Pacific regions, while the opposite was noted in the Americas. Adolescents were less likely to report attempting suicide per unit of GDP increase in the Americas and the South East Asian regions while there was no association in Africa, East Mediterranean and the Western Pacific. The pupil to teacher ratio was associated with lower odds of suicide attempts in Africa and South East Asia. Students were more likely to report suicide attempts per unit increase in the homicide rates in the Americas and South East Asia, however, the opposite was observed in Africa. Adolescents were less likely to attempt suicide with a per unit increase in the population density in the African, the Americas and the Western Pacific regions. Suicide law was not associated with suicide attempts, while the night light development index had a negative association in the Americas. Estimates are presented in Table 8.

Table 8: Mixed effects logistic regression model estimates (Suicide attempts).

Variables	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
	AFRICA		AMERICAS		EAST MEDITERRANEAN		SOUTH EAST ASIA		WESTERN PACIFIC	
Age (continuous)	1.03	0.99, 1.09	0.99	0.96, 1.02	1.13	1.05, 1.22	0.95	0.90, 1.01	1.03	0.99, 1.07
Sex (Ref: Male)	1.10	0.98, 1.24	2.02	1.88, 2.17	1.80	1.46, 2.22	1.61	1.39, 1.86	1.54	1.42, 1.68
Went hungry	1.55	1.30, 1.84	1.00	0.85, 1.18	1.33	0.98, 1.82	1.24	0.95, 1.60	1.24	1.08, 1.43
Attacked	1.58	1.38, 1.80	1.42	1.32, 1.54	1.21	0.99, 1.49	1.22	1.05, 1.43	1.45	1.33, 1.60
Physical fighting	1.36	1.19, 1.56	1.37	1.27, 1.48	1.27	1.03, 1.57	1.23	1.05, 1.45	1.33	1.21, 1.45
Injured	1.64	1.43, 1.88	1.33	1.24, 1.43	1.68	1.38, 2.04	1.57	1.34, 1.83	1.71	1.56, 1.88
Bullying victimization	1.60	1.41, 1.82	1.54	1.43, 1.66	1.94	1.58, 2.38	1.63	1.40, 1.90	2.00	1.82, 2.19
Loneliness	1.78	1.52, 2.09	2.29	2.09, 2.51	2.25	1.79, 2.81	2.20	1.81, 2.67	1.91	1.71, 2.13
Anxiety	1.90	1.61, 2.24	2.15	1.95, 2.38	1.74	1.37, 2.21	2.45	1.98, 3.02	1.91	1.69, 2.16
No close friends	1.59	1.31, 1.92	1.65	1.45, 1.89	1.62	1.16, 2.25	3.94	3.14, 4.94	2.49	2.15, 2.88
Truancy	1.41	1.23, 1.61	1.36	1.27, 1.46	1.27	1.04, 1.55	1.53	1.32, 1.78	1.42	1.30, 1.55
Helpful peers	0.97	0.85, 1.11	0.91	0.84, 0.97	0.75	0.62, 0.92	0.97	0.84, 1.12	0.87	0.79, 0.95
Supportive parents or guardians	1.01	0.89, 1.15	0.70	0.65, 0.75	0.74	0.60, 0.91	0.72	0.61, 0.83	0.81	0.74, 0.90
Alcohol/smoke cigarettes	1.68	1.46, 1.94	1.87	1.74, 2.02	2.26	1.75, 2.93	2.12	1.77, 2.53	2.11	1.92, 2.32
Gini coefficient	1.05	1.04, 1.06	0.93	0.92, 0.95	0.96	0.90, 1.01	1.10	0.97, 1.25	1.11	1.02, 1.22
GDP per capita	0.96	0.92, 1.01	0.87	0.84, 0.90	0.93	0.81, 1.06	0.76	0.62, 0.93	0.94	0.81, 1.10
Pupil to teacher ratio	0.95	0.94, 0.97	1.01	0.99, 1.04	NA		0.96	0.94, 0.97	1.07	1.00, 1.15
Homicide	0.92	0.88, 0.96	1.01	1.00, 1.02	NA		1.95	1.36, 2.79	1.04	0.92, 1.17
Population density	0.55	0.38, 0.79	0.63	0.57, 0.71	NA		NA		0.62	0.40, 0.95
Suicide law	1.20	0.96, 1.50	NA		NA		NA		NA	
Night light index	NA		0.01	<0.01, 0.06	NA		NA		NA	

OR is Odds Ratio; CI is Confidence Interval

6 Discussion

In Seychelles, external causes of mortality comprised 8.5% of the all-cause mortality, with drowning as the leading cause of injury mortality from 1989 to 2018. While there was a slight annual decline in the injury mortality among the males, there was a slight increase among females during the 30-year period. TBIs accounted for 2.5% and 0.6% of the all-cause mortality among males and females respectively. They also accounted for 21.9% and 14.3% of the external causes among males and females respectively, with road traffic crashes being the leading mechanism of injury. Males were over-represented both in all injuries and in TBI-related mortality.

In the pooled results, 10% of the adolescents reported having had suicidal thoughts, 10% made a suicide plan, while 11% had attempted suicide in the 12 months preceding the surveys.

This research study utilized data collected in LMICs; from the civil registration and vital registration system which is comprehensive and representative of the entire population in Seychelles as well as from cross-national surveys that were nationally representative of school going adolescents in each respective country that was included.

6.1 External Causes of Mortality

The proportion of injury mortality in Seychelles was close to the global estimate of 10% [1,3,4]. According to other studies conducted in the African region, it has ranged from 4 – 25% [7,37,115,116]. The studies with higher estimates had data sources from hospitals and police records meaning injuries could have contributed to a higher hospital population mortality relative to other causes. On the other hand, these estimates may be underestimated due to death cases that fall completely outside of the health and civil death registration system. Injury cases who die near their homes or in rural settings and are buried without a medico-legal examination of the cause of death or who were never under the care of medical personnel at the time of death or where no social autopsy was performed to assess the cause of death are likely to be missed.

Males were over-represented in the injury deaths which is similar to estimates observed in other African studies at 80% and above [48,116], although slightly lower estimates ranging from 56 – 71% have also been reported [6,7,9,37,117]. The higher injury mortality among males may occur because they are more likely to be daring, or are exposed to occupational hazards, for example, fishing [9,117], and the road traffic environment in the case of Seychelles.

The injury age standardized mortality rate was 105.5 and 25.4 per 100 000 person-years for males and females, respectively over 30 years. The estimate is close to what was reported in Seychelles at the rate of 111 and 26 between 1989 to 1991; which reduced to 79 and 23 among males and females respectively between 2008 to 2010 [108]. The rates are close to the age standardized rate of 99 per 100 000 population reported in Africa, and ranging between 70 – 127 in other LMICs [1,46,118].

Drowning contributed to a majority of the injury mortality cases in Seychelles; and by sex, this was only among males. The drowning age standardized mortality was highest among the 40 – 59 age group at 8.2 deaths per 100 000 male person-years. While some studies have found a higher mortality only among children and adolescents [21], this study found the least mortality rate among the 0 – 19 year olds in males for drowning. Similar findings for drowning as the leading mortality rate among adults have been found in Ethiopia [7]. Fishing as an economic activity was associated with drowning among adults and the children of fishermen in Malawi and Tanzania [9,117]. The higher drowning mortality in this study among the economically active male population could be attributed to fishing as a means of occupation and inadequate protection considering that Seychelles is an archipelago located in the Indian Ocean. Fishing is considered to be within the primary sector in the labor sector in Seychelles and a major source of livelihood contributing to 8% of the country's GDP [119]. Commercial fishing is a high risk occupation, with unstable and adverse weather conditions that may cause boats to capsize or falls overboard leading to drowning [120]. Moreover, falls on the decks of boats are also very common mechanisms of injury leading to, for example, head injuries.

Road traffic injuries were the second leading cause of injury related mortality in Seychelles. The age group affected most were the males aged 20 – 39 years at 8.1 per 100 000 male person-years. Several studies have found high rates of road traffic mortality among the youth and economically active population [31,38,48,116,118]. The high mortality could be attributed to more exposure in the traffic environment. Additionally, the presence of traffic violations and inadequate enforcement of traffic laws poses a threat to the population and increases the risk for traffic related injuries [6]. Additionally, mortality from road traffic injuries as a proportion of all injuries across all ages for both sexes was 17%, which is less than the observed global estimate of 23 – 29% [4,118], and in Guinea and Uganda ranging from 37 – 46%

[6,115]. The African studies that reported a higher proportion used data from hospital registers thus reflecting an over-representation of a severely injured population as opposed a civil register. The increasing trend in road traffic mortality is also consistent with results from LMICs [3]. Strategies like enforcement of safety traffic rules and separation of pedestrian and vehicle traffic could potentially offset the rise in traffic fatalities, leading to a decline in traffic related deaths.

The other unintentional injuries category was the leading contributor to injury related mortality among the females. The older females aged 60 years and above accounted for 68.3% of the mortality in this injury category. The age standardized mortality rate among the females in this age group was 8.0 per 100 000 female person-years, with the highest rate at 11.5 between 2009 to 2013. The cases with hip, and limb fractures for which the cause of injury was unspecified were categorized into the other unintentional injuries in this study. Thus, it is possible that the limb fractures among the elderly may have been sustained through falls. Therefore, it is possible that the fall mortality rate could have been under-estimated in this study, considering it is one of the leading causes of injury mortality among the elderly. According to the population data in Seychelles, approximately 60% of the female population are 60 years and older. With the population gradually aging, it is important to plan for better health care and support in the event of falls, especially for the older populations [13]. The higher proportion of other unintentional injuries observed among women could also have been due to women living longer or were older widows and/or live alone. Additionally, the infections from the limb fractures could also have contributed to the higher mortality within this age group.

6.2 Traumatic Brain Injury Mortality

Regarding TBI related mortality, the present study revealed, on an age standardized basis, a rate of 22.6 and 4.0 per 100 000 person-years among males and females respectively in Seychelles. During the three 10-year periods, the rate was 28.1, 22.3 and 20.1 among males and 3.0, 3.9 and 4.6 among females. An analysis of the 15-year periods and 5-year periods depicted a similar trend with a decline among males which indicated a consistency as observed during the 10-year periods.

The age groups with the highest mortality varied among males and females. For instance, it was the economically active age group 20 – 39 for males and the pediatric and teenage population 0 – 19 years for the females. In other LMIC studies, one of the risk factors for TBI mortality was being age 50 and older in Rwanda [10]; and above 60 years in Ethiopia [121]. However, both studies had a hospital-based cohort of patients who were recruited from the emergency wards. A Chinese population based study also reported the highest TBI age-standardized rate among those 75 years or older [122]. Among the males in Seychelles, the variation could be attributed

to more males being injured through traffic and occupation environments. Additionally, majority of the injuries among the females also occurred through traffic injuries (66.0%). More than half of the road traffic victims in an Ethiopian study were pedestrians [121], thus it is possible that the female pediatric population were pedestrians going to or from school. However, the Seychelles data did not include information on whether the victims were pedestrians or passengers in a vehicle.

Road traffic injuries were a leading contributor to TBI-related mortality over the 30-year period. It was also the case only for the last 2 decades, from 1999 to 2018. Road traffic crashes significantly contribute to TBI mortality in LMICs [10,121]. This could be attributed to males being more economically active and potentially sustaining injuries in the traffic environment. Moreover, the risk of death due to a TBI as a result of a high velocity road traffic collision is higher than other mechanisms, for instance, the risk from a fall less than 2 meters due to the difference in severity of the injuries [123].

Falls were the second leading mechanism of TBI-related mortality. Falls have also been reported as a leading cause of TBI-related mortality among HICs [64,80]. Although the population in Seychelles is ageing, a different trend in fall mortality was observed compared to HICs. The TBI fall mortality rate among the individuals 60 years and above was 0.6 per 100 000 person years among males with none reported among females 40 years and older. It is possible that the falls among the older population contributed to other causes of mortality but not TBIs. This means that any falls that may have occurred among the older females may not have directly contributed to TBI deaths during the study period in Seychelles. In contrast, increased mortality due to TBI and hip fractures has been observed in North-American studies among the older population, majority of whom were women and more likely to be injured through falls [124].

Studies from Ethiopia and Rwanda have reported assault/homicide [10,121] as the second contributing mechanism to TBI deaths after road traffic crashes. The TBI mortality associated with homicides in our study was quite low and subsequently lumped together with drowning, suicide, fire-related burns, and other unintentional injuries.

External causes with undetermined intent were a significant contributor to TBI-related mortality in Seychelles. Furthermore, they were the leading contributor to TBI mortality from 1989 to 1998 only. In general, a decline in the mortality rate was observed throughout the 30-year period of the study. It is possible that in the first decade of this study, external causes with undetermined intent could have been inadequately classified during the registration process and improved over time leading to a reduction of TBI-related mortality within this category, which ultimately showed a significant decline in trend over time.

6.3 Suicidal behavior among adolescents

The strongest risk factors across the various regions included feeling lonely, feeling anxious in the form of worrying to an extent that one could not sleep at night, the female gender, and smoking cigarettes and/or the use of alcohol, and a lack of close friends. Apart from the African region, adolescents were less likely to report suicidal behavior if they had helpful peers at school as well as understanding parents or guardians. Within the African region, the statistically non-significant association with understanding parents or helpful peers at school on suicidal behavior could be attributed to social integration. With social cohesion at the family and community levels, individuals are normally able to seek support from any family member within the extended family regardless of whether it is a guardian or parent [82], which adolescents may have taken advantage of.

The country level covariates (the GC, GDP per capita, the pupil-to-teacher ratio in primary schools, the population density, the intentional homicide rate, the law on suicide and the night light index) were not significant in the random effects models. The random effect allows for group level explanatory variables to explain between group variation, in the adolescent suicidal behavior in this case. Since it was not significant, the exact effect of the country level variables may have been homogenous. For example, using the Gini coefficient, the exact effect of the Gini coefficient on suicidal behavior did not vary from country to country.

As fixed effects, a unit increase in the country Gini coefficients was associated with adolescents being less likely to engage in suicidal behavior in the Americas, and the East Mediterranean region. In contrast, African adolescents were more likely to engage in suicidal behavior with each unit increase in the Gini coefficient. Considering that the Gini coefficient is a measure of unequal distribution of income in a country, with a higher value indicating a higher level of inequality, it is possible that the adolescents from the African region were aware of the unequal distribution of incomes within which in turn adds to feelings of frustration. While the adolescents from African region may have adequate social support [82], the overall poverty levels combined with inequality could influence suicidal behavior. The implication from the Americas and East Mediterranean may be that in the countries where more inequality was recorded, the adolescents were more resilient and less likely to engage in suicidal behavior. This could be attributed to the social support from the family structures or extended families in the East Mediterranean [86]. Additionally, their religious beliefs and practices could potentially offset some negative effects.

Similarly, adolescents were less likely to engage in suicidal behavior with a unit increase in the GDP per capita in the Americas, the East Mediterranean and in South East Asia regions, while the reverse was observed in the African region. While GDP per capita is a measure of wealth in a country, it does not mean that everyone in the

country has the same level or access to wealth. Therefore, it is likely that the adolescents from the Americas, East Mediterranean and the South East Asian regions may have felt more secure financially, and never had to worry about their living situations or basic needs [104]. Albeit, within the African region which already had the lowest GDP per capita, the adolescents may have worried about their basic needs and requirements considering that at the regional levels, the highest proportion of adolescents who had stayed hungry during the GSHS survey was in the African region.

An increase in the country pupil to teacher ratios was associated with adolescents being less likely to engage in suicidal behavior in the African and the South East Asian regions, which was consistent with a Chinese study [104]. However, a higher ratio was associated with more likelihood to engage in suicidal behavior in the Americas. A high population of pupils in the classroom could contribute to social cohesion and support for one another among each other, however, it could also be considered as overcrowded depending on the assessor. This may be the case for adolescents in the African and South East Asian countries. In the Americas, where the local culture may be more individualist, with less of a tendency to rely on social networks, there may be less social cohesion and feelings of acceptance among adolescents in the Americas. Additionally, it is possible that adolescents in the Americas face their personal difficulties without sufficient help or support from peers or teachers, hence contributing to engagement in self-destructive behavior.

Adolescents were less likely to engage in suicidal behavior with a unit increase in the population density in the African region and the Americas. It may be assumed that a rural area would have a lower population density with the reverse in an urban area. The implication is that adolescents who lived in urban areas were less likely to engage in suicidal behavior [39]; however, that was not possible to ascertain in this study. In this case, the population density figures were based on the national level averages for each country in the study. Thus, the density was related to the population and surface area in a country. It is possible that countries with a smaller population were better able to provide improved services to their population compared to those with larger populations. Additionally, a higher population density would mean more people per square kilometer, thus adolescents potentially had more family, friends and community support.

Students were more likely to engage in suicidal behavior with each unit increase in homicide rates in the Americas and in South East Asia. While the reverse was observed for the African region. The higher likelihood of homicide in the Americas and South East Asia may be related to the inequality of access to the resources in the regions [125]. An examination of adolescent inpatients found suicide ideation in 66.9% of those who reported homicidal ideation [126], implying the two may be correlated. It is also possible that the stressful social events that contribute to suicidal

behavior also influence intentional homicide. In Africa, adolescents may have developed resiliency and coping mechanisms as a result of living in dangerous surroundings. They may have adapted through situational awareness in their environments and taking precautions to stay safe, e.g., by avoiding walking alone in unsafe areas.

The suicide law in a country was not statistically associated with suicidal behavior in any of the regions, except in Africa for suicide ideation. Suicide laws that criminalize suicidal behavior were established as deterrents against suicide [40]. Suicide is considered a personal matter and it aims to end personal suffering and lead to the attainment of peace and rest from the troubles of living [83,84]. Thus, individuals may still proceed to take their own lives even in the face of deterrent laws if they believe it is necessary. Moreover, suicidal individuals may believe that other persons in their social systems do not understand them and sometimes may not openly communicate their feelings [86]. Since the motivation is to achieve peace and end one's suffering in the world, laws against suicide may be ineffective. Countries with punishable laws on suicide attempts do not necessarily have lower suicide rates compared to countries without punishable laws [40].

Adolescents were less likely to engage in suicidal behavior per unit increase in the night light index in the Americas. Due to multicollinearity, the night light index was not included in other regional models. However, when all countries were pooled together, an increased risk of exposure to the night light was associated with suicidal behavior. A study conducted in South Korea also found suicidal behavior was associated with increased exposure to night light [101]. Further research within the context of LMICs is warranted.

6.4 Strengths and limitations

Nationwide population-based studies on African populations are rare. This study provided an opportunity to estimate the injury mortality in an African nation. The data extraction for the entire duration of the study was done by the same person, and thus minimized different interpretations during the data entry process from different persons. The registration of civil registration and vital statistics in the Republic in Seychelles is comprehensive and captured data from the entire population. According to the World Bank, the civil registration of death coverage in Seychelles was at 98.8% in 2002, 100% in 2011, and 91% in 2015 [111]. Therefore, the estimates are not from a sample but represent the Seychelles population.

A limitation of the study is that the data was not detailed enough to determine mortality rates by location, for example, the mortality in the different districts and municipalities in the country. The duration between the date of injury and death was also not available to estimate associations and other–such treatment- or comorbidity-

related–factors that may have contributed to the mortality. Additionally, the extremely few injury numbers, especially among females could have led to unstable and inconclusive mortality estimates for this category as well as other injury categories with smaller numbers. Furthermore, the dataset was not specific on etiology, which limited the epidemiological analysis of the data.

Furthermore, the number of suicides in Seychelles may have been underreported in the civil registration systems due to various cultural definitions and acceptable norms for suicides and poisonings. Chronic drug use cases were included among the poisoning category as it may have indirectly been a contributing factor. Thus, while the criterion for poisoning is specific to drug overdose in some cases based on the registration system, this study included all drug addict and abuse cases wherever they were included in the death certificates. Some asphyxiation cases were difficult to discern the intent, for example, if they were due to homicide or suicides and thus were included within the undetermined intent category.

The study on adolescent suicidal behavior used data from standardized surveys that are nationally representative at the country levels and validated internationally. Using this study, we were able to add knowledge about the prevalence of suicidal behavior among adolescents in LMICs and the associated contextual factors. However, since the survey was cross-sectional, it is possible for recall bias to have occurred. Additionally, considering the stigma surrounding mental health, the respondents may have modified their responses leading to an underestimation or overestimation of the suicidal behavior prevalence. Adolescents not in school did not participate in the survey, and since they are a distinct and vulnerable group, the issues affecting them were not included in the survey and results. Adolescents out of school tend to have challenges that may not be similar to those in school, for instance, early or forced marriages or child labor. These factors may influence their behavior in different ways and make them more vulnerable, thus it would be important to capture their issues as well.

6.5 Future Research Perspectives

This is the first study on external causes of mortality that used a civil registration and vital statistics system in its entirety in the African region. It would be beneficial to contribute further to injury research to produce evidence that will be applicable to LMICs. Therefore, as a start, other LMICs could improve their respective civil registration systems so that it is possible to conduct research in the entire country and find interventions that are relevant to their context. While the results from Seychelles may not be generalizable to other larger and non-island countries, the research has also provided insight on injury mortality at a national level in an African country. Future research could focus on using additional information on the injuries,

for example, the location of the injuries, the duration of stay in hospital, among others. These additional data will contribute to additional research that could explore the etiology of injuries and which locations would require targeted interventions to reduce the incidence.

The suicidal behavior reported among adolescents in LMICs warrants further research in exposure factors. Considering that mental health is associated with stigma, interventions that aim to demystify it may go a long way to improve uptake and provision of mental health services targeting adolescents both in and out of school.

7 Summary/Conclusions

In the Republic of Seychelles, injuries contributed to nearly 1 in 10 deaths out of the all-cause mortality, with 1 in 10 among males and 1 in 20 among females. Drowning was the leading cause of injury related mortality among males, while the other unintentional injuries were the major contributor among females. In general, the major injury contributors to mortality vary by region, country, and various locations within a country as well as by age and sex. Overall, there was a decline of injury mortality among males; although, the trend seemed stagnant among females. There was also an increase in road traffic injury related mortality among males during the 30-year period.

TBI related deaths occurred in 1 out of 5 injury deaths. There was a reduction in the age standardized TBI-related mortality over the course of 30 years, especially among males. Road traffic crashes were the leading contributor to TBI-related mortality and mostly affected males in the economic age, while among females, the highest rate was recorded among the 0-19 age group. Fall-related TBIs occurred in 1 out of 10 TBI deaths, thus it was among the top three mechanisms of injury. However, no fall-related TBI deaths were recorded among females 40 years and older during the 30-year period.

The prevalence of suicidal behavior varied by country and geographical region. Several individual level variables were significantly associated with suicidal behavior, for example, feeling lonely, worried or anxious, a lack of close friends and the use of alcohol and/or smoking cigarettes among others. However, the study failed to find a statistically significant association with some of the country-level contextual variables or mixed findings across the various regions that were investigated. The non-significant country level findings were not entirely surprising given the mixed results from prior studies.

These findings fall against the backdrop of continuous efforts aimed at assessing and monitoring injury and suicidal behavior globally.

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