BMC Public Health

RESEARCH

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# Methodological considerations in injury burden of disease studies across Europe: a systematic literature review

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## Abstract

**Background:** Calculating the disease burden due to injury is complex, as it requires many methodological choices. Until now, an overview of the methodological design choices that have been made in burden of disease (BoD) studies in injury populations is not available. The aim of this systematic literature review was to identify existing injury BoD studies undertaken across Europe and to comprehensively review the methodological design choices and assumption parameters that have been made to calculate years of life lost (YLL) and years lived with disability (YLD) in these studies.

**Methods:** We searched EMBASE, MEDLINE, Cochrane Central, Google Scholar, and Web of Science, and the grey literature supplemented by handsearching, for BoD studies. We included injury BoD studies that quantified the BoD expressed in YLL, YLD, and disability-adjusted life years (DALY) in countries within the European Region between early-1990 and mid-2021.

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**Results:** We retrieved 2,914 results of which 48 performed an injury-specific BoD assessment. Single-country independent and Global Burden of Disease (GBD)-linked injury BoD studies were performed in 11 European countries. Approximately 79% of injury BoD studies reported the BoD by external cause-of-injury. Most independent studies used the incidence-based approach to calculate YLDs. About half of the injury disease burden studies applied disability weights (DWs) developed by the GBD study. Almost all independent injury studies have determined YLL using national life tables.

**Conclusions:** Considerable methodological variation across independent injury BoD assessments was observed; differences were mainly apparent in the design choices and assumption parameters towards injury YLD calculations, implementation of DWs, and the choice of life table for YLL calculations. Development and use of guidelines for performing and reporting of injury BoD studies is crucial to enhance transparency and comparability of injury BoD estimates across Europe and beyond.

**Keywords:** Burden of disease, Burden of Injury, Disability-adjusted life years, Review, Methodology

## Background

Across the global burden of disease (BoD) landscape, injuries are a major public health problem. There have been significant declines in case fatality rates from severe injury over recent decades, indicating that access to trauma care systems have led to improvements in survival [1, 2]. However, survivors of severe injury often develop long-term disabilities, resulting in significant losses of healthy life years, long after the acute injury. Most injury-related epidemiological studies have focused on using incidence, case fatality rates, or population mortality rates to describe the public health impact of injuries [3–5]. Considering that non-fatal consequences of injury vary widely in their severity and duration, and that premature mortality is an important injury consequence, it is of great importance to use a summary measure of population health that includes both mortality and morbidity when assessing the impact of injury.

A widely used population health indicator combining the impact of mortality and morbidity is the disability-adjusted life year (DALY) [6, 7]. The DALY – used in the Global Burden of Disease (GBD) study – quantifies the BoD by merging mortality, expressed in years of life lost (YLL) and morbidity, expressed in years lived with disability (YLD) into one single metric [7]. Historically, the BoD concept allows for both geographical and temporal comparisons of the impact of different diseases and injuries on population health [7, 8].

Many countries and public health agencies have adopted the DALY metric for monitoring population health and identifying priorities in preventive efforts; however, calculating the burden due to injuries is complex. It requires adequate epidemiological data from a range of administrative sources that include information on the *cause-of-injury*, which pertains to the intent and mechanism of injury, and the *nature-of-injury*, which pertains to the type of injury and the severity of their consequences [9]. Furthermore, calculating the burden due to injury requires many specific methodological choices, particularly for the non-fatal consequences [10, 11]. First, a choice has to be made as to whether incidence-based or prevalence-based injury YLDs are to be calculated [12]. Incidence-based YLD calculations capture the current and future BoD of incident cases and may be more useful to inform injury intervention strategies compared to prevalence-based calculations. Second, to assess injury YLDs, a methodological approach and data are required to inform short-term and long-term disability based on post-injury functional status. A third methodological choice relates to the set of disability weights (DWs) that is applied to injury-related health states. Several sets of DWs exist with ranging coverage of injury-related health states [13, 14].

Another methodological choice relates to the calculation of the YLLs. For the calculation of YLLs, information on the remaining life expectancy at age of death is needed and this is derived from aspirational or standard (i.e., observed global life expectancy) or national (i.e., national life expectancy) life tables. In BoD studies, the choice of the life table affects the magnitude of the YLL and as a result affects country and time-period comparability [15].

Driven by the disparity in the mortality and morbidity injury patterns across Europe, where many independent BoD studies have been published, there is a need to explore which injury BoD design choices have been applied over the years. Until now, an overview of the YLL and YLD design choices that have been used in BoD studies in injury populations is not available. Therefore, we aimed to identify existing injury BoD activities undertaken in Europe and to comprehensively review the methodological design choices and assumption parameters that have been used to calculate YLL and YLD in these studies. The following research questions were addressed:

- In which GBD European Region countries has injury BoD assessment been performed?
- Which YLD methodological design choices and assumption parameters have been made in single-country and multi-country injury BoD assessments?
- Which YLL methodological design choices and assumption parameters have been made in single-country and multi-country injury BoD assessments?

## Methods

The design of this systematic literature review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [16]. The protocol can be found on PROSPERO under the registration number: CRD42020177477.

### Inclusion and exclusion criteria and injury definitions

In this literature review, we included studies that assessed the health outcomes from injury in terms of YLL, YLD, or DALY. Our review is limited to injury-specific BoD studies; we have excluded studies that reported on all-cause disease burden. All-cause BoD studies assess the impact of multiple causes covered by the three broad GBD cause hierarchy groups namely Group I "Communicable, maternal, neonatal, and nutritional diseases", Group II "Non-communicable diseases", and Group III "Injuries". Injury-specific BoD studies assess the impact of the GBD cause-of-injury and/or nature-of-injury outcomes and did not assess YLL, YLD, or DALY resulting from Group I and/or Group II. Details of the GBD 2019 disease and injury hierarchical cause list can be found elsewhere [17]. We included only BoD studies conducted within the GBD European Region. A full list of these geographic locations can be found in the Additional file 1 (page 2). Since the DALY concept was introduced in the 1993 World Development Report [18], we screened only BoD studies published after January 1990.

We excluded disease burden studies that did not assess the impact of injury causes. We also excluded studies that quantified the magnitude of risk factor exposure, because methodological approaches for the risk factor assessment were beyond the scope of this review. Further, we excluded studies with outcomes other than YLL, YLD and/or DALY (e.g. computation of potential years of life lost, estimation of DWs), as well as citation-only books, theses, conference proceedings, editorials, and letters-to-editor.

We considered BoD studies that defined injury as a physical harm resulting from acute exposure to physical agents such as mechanical energy, electricity, heat, chemicals and radiation in amounts beyond the threshold of human tolerance [19]. We used the International Classification of Diseases (ICD) system to identify causes-of-injury, where the injury incidence and causes-of-death are defined in ICD-9 codes E000-E999 and ICD-10 chapters V–Y. Non-fatal consequences of injuries and poisonings are classified based on ICD-9 codes 800–999 and ICD-10 chapters S and T. Thus, we included studies assessing the injury burden in terms of nature-of-injury and cause-of-injury. We did not include psychological (e.g. post-traumatic stress disorder) or pathological consequences (e.g. osteoporotic fractures) resulting from a prior trauma. An overview of the GBD cause-nature categories can be found in the Additional file 1 (page 3).

### Data sources and search strategy

We searched for eligible BoD records on five main platforms: EMBASE, MEDLINE, Cochrane Central, Google Scholar, and Web of Science. An experienced librarian from the Erasmus MC Medical Library performed the search strategy on 2 April 2020, updating it on 6 May 2021. We did not set any language restrictions. Details of the systematic search strategy can be found in the Additional file 1 (page 5).

We examined the grey literature on: (a) OpenGrey, OAIster, CABDirect, and the World Health Organization (WHO) websites and (b) government and/or public health websites from the targeted European countries (see Additional file 1; page 8). We also asked the COST Action CA18218 members to identify further all-cause or injury-specific BoD sources. One researcher (PC) hand-searched references of those eligible and included BoD records by looking into the references of published studies and reports.

### Screening and data extraction

We listed all the records obtained from the search strategy (phase 1) and the COST Action CA18218 participants (phase 2) on an EndNote X9 and Excel spreadsheet, respectively. After removing duplicates, we imported all the records on the EndNote X9 software. Two researchers (PC and VG) performed the screening. In essence, we selected eligible studies following three steps: title (first step) and abstract screening (second step), followed by our identifying potentially relevant studies and screening upon full-text (third step). Discussions with EP and the study supervisor (JH) resolved any doubts.

Two researchers (PC and EP) performed the extraction of data, independently of each other, using an Excel spreadsheet which included the following a priori information: first author, year of publication, country or region, study type, type of analysis, methodological choices regarding the YLL and YLD calculations, and injury-specific approaches for BoD calculations. The extracted items, followed by their definitions, can be

found in the Additional file 1 (page 9). We piloted the data extraction grid for 5% of the included BoD studies with no masking, during this process. Data extraction for the non-English papers was performed by the *burden-eu* native speakers and discussed with PC. Finally, PC and EP compared, assessed, and discussed the data extraction forms. Discussions with the study supervisor (JH) resolved any disagreements.

### Study classifications

In this review, we classified studies according to the: (a) number of countries that were covered (single-country *versus* multi-country BoD study), (b) reported causes of ill-health (all-cause *versus* injury-specific BoD study) and (c) type of study (independent *versus* GBD-linked injury BoD study). The term *'independent injury BoD study'* refers to single-country or multi-country studies for which researchers performed own calculations and analyses of YLL, YLD and/or DALY caused by injuries. The term *'GBD-linked injury BoD study'* refers to single-country or multi-country studies that present GBD estimates or secondary analyses of GBD results. In this group, we also classified studies in which the injury YLL, YLD, and/or DALY estimates were derived from the WHO Global Health Estimates (GHE) [20], though the GHE and GBD are two separate repositories.

The following review focuses on the summary of single-country and multi-country independent and GBD-linked injury-specific BoD studies that have been performed across European countries over the 1990–2021 period. Descriptive analysis and the reference lists of the identified all-cause-related European BoD studies can be found in the Additional file 1 (page 12).

## Results

### Literature search

We retrieved a total of 2,771 articles from the developed search strategy (EMBASE = 1,791; Web of Science = 560; MEDLINE via Ovid engine = 261; Google Scholar = 128; and Cochrane library via Wiley engine = 31). We identified 327 additional records via other methods (i.e., grey literature and citation handsearching). After removing duplicates, we screened a total of 2,914 records. We performed full-text screening for 292 BoD studies, and we extracted data from 125 BoD studies. Out of these 125 BoD studies, 48 performed an injury-specific disease burden assessment. Figure 1 shows the flowchart of the literature search strategy of existing disease burden studies and main reasons for exclusion.

### Study types per study classification and geographic location

As described in Table 1 and Fig. 2, 40% (19 out of 48) consisted of GBD-linked studies, whereas 60% (29 out of 48) consisted of independent studies. Of the GBD-linked studies, 89% (17 out of 19) were multi-country studies and 11% (2 out of 19) were single-country studies. Of the independent studies, 28% (8 out of 29) were multi-country studies and 72% (21 out of 29) were single-country studies. Single-country injury disease burden assessments ($n = 23$) were performed in 11 European countries. The largest number of single-country independent studies was observed in the Netherlands ($n = 11$), followed by Scotland ($n = 2$), Belgium ($n = 2$), Germany ($n = 1$), Sweden ($n = 1$), Italy ($n = 1$), Norway ($n = 1$), France ($n = 1$), and Russia ($n = 1$). Two single-country studies undertaken in Poland ($n = 1$) and England ($n = 1$) assessed the burden of injuries using GBD results.

### Cause-of-injury *versus* nature-of-injury burden of disease studies

Figure 3 illustrates the number of GBD-linked and independent injury BoD studies ($n = 48$) by cause-nature of injury. In total, 38 out of 48 studies reported the BoD by cause-of-injury category, and the remaining 10 studies reported the BoD by nature-of-injury category. The majority of the cause-of-injury BoD studies were GBD-linked studies (24 out of 38). Nine out of these 24 studies evaluated the impact of road injuries. In contrast, among the independent studies that reported cause-of-injury (14 out of 38), the number of multi-cause (7 out of 14) and suicide and/or self-harm (3 out of 14) studies stand out. Moreover, the number of independent studies that reported nature-of-injury (7 out of 10) was higher compared to the number of GBD-linked studies (3 out of 10). The largest number of independent nature-of-injury BoD studies assessed the impact of hip fractures (2 out of 7), and traumatic brain injury and/or spinal cord injury (2 out of 7).

### Classification of injury diagnosis

Single-country and multi-country GBD-linked studies (17 out of 19) re-ordered injury causes-of-death using the ICD-9 or ICD-10 coding system. Two of these studies (2 out of 19) did not report the injury classification scheme. Similarly, most single-country and multi-country independent BoD studies (82%) gathered injury diagnosis from the ICD code-system. Some of these studies (38%) translated injury diagnosis according to the EUROCOST classification system [21]. Three single-country and multi-country independent injury studies (11%) did not report the diagnosis classification system.

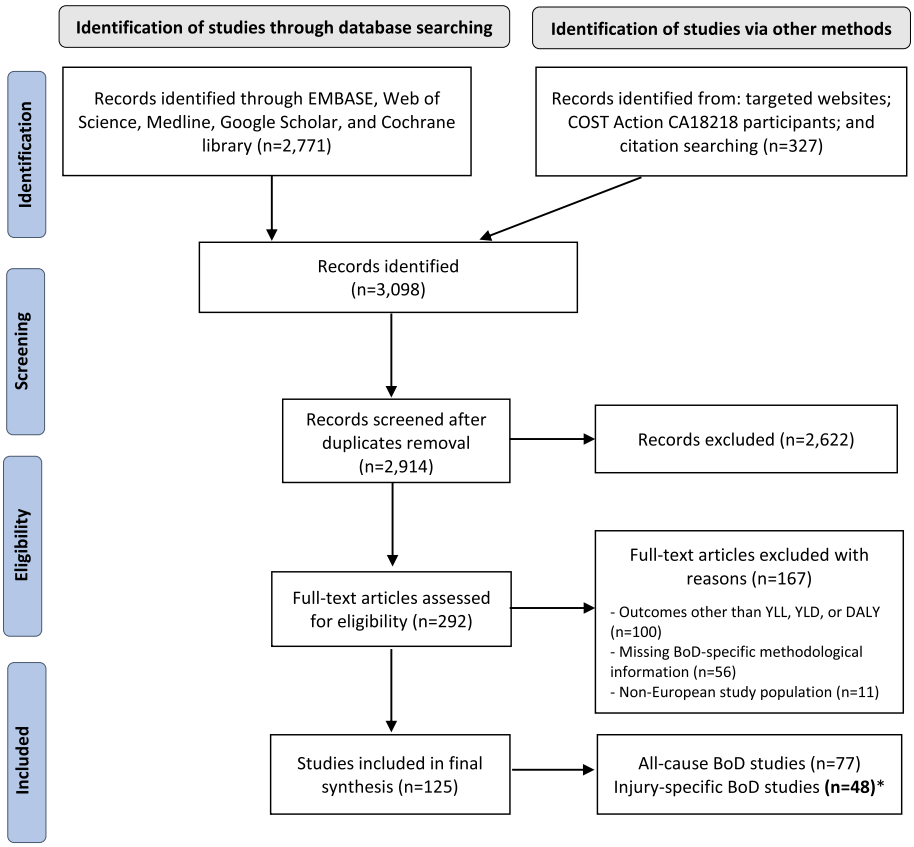


**Fig. 1** Flowchart of the literature search strategy of existing European burden of disease studies

* This systematic literature review is limited to injury-specific BoD assessments undertaken across Europe; January 1990 - May 2021

**Table 1** Number of GBD-linked and independent single-country and multi-country studies

| | *Injury-specific BoD studies (n = 48)* | |
|---|---|---|
| | **GBD-linked BoD assessments** | **Independent BoD assessments** |
| Single-country | *n* = 2 (11%) | *n* = 21 (72%) |
| Multi-country | *n* = 17 (89%) | *n* = 8 (28%) |

## YLD methodological choices in injury burden of disease studies

### *Prevalence-based versus Incidence-based calculations*

Table 2 summarizes the methodological design choices and assumption parameters that have been used in injury BoD studies. Most single-country independent studies have followed the incidence-based approach to calculate YLDs due to injury [22–38]. Two independent injury BoD reports conducted in Scotland have performed own prevalence-based YLD calculations [39, 40]. Conversely, two single-country studies have evaluated the impact of injury using GBD results; a United Kingdom comparative report presented prevalence-based YLD calculations [41], and a Polish study quantified injury DALYs using a combination of Polish data on traffic fatalities and GBD 2010 data to assess the burden due to traffic injuries in Warsaw [42]. Seven multi-country independent studies quantified the burden of injury using the incidence-based approach [43–49]. Also, 11 multi-country GBD-linked studies estimated injury YLDs using the prevalence-based approach [1, 50–59]; of which 10 used GBD data as primary source of data and one of these studies used the 2015 WHO GHE as a primary source of data. Moreover, four out of the 11 multi-country GBD-linked studies followed an incidence-based approach to assess injury YLD. [60–63]. These four injury BoD studies were conducted before 2010.

### *Use of disability weights*

Several sets of DWs were used to assess injury BoD estimates in independent studies. More than half (56%) of these studies, applied empirical DWs [25, 27, 29–34, 36–38, 43, 45, 48, 49]. All independent studies that used empirical DWs have performed incidence-based YLD

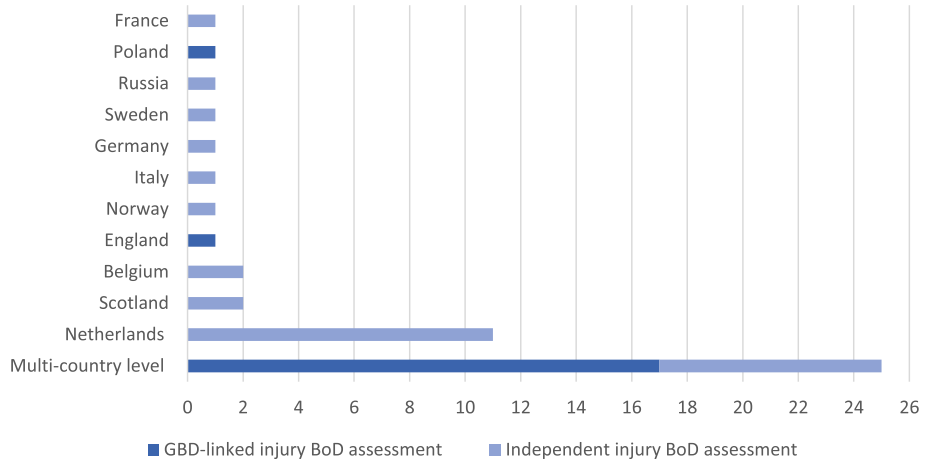


**Fig. 2** Number of GBD-linked and independent injury burden of disease studies per multi-country and single-country category

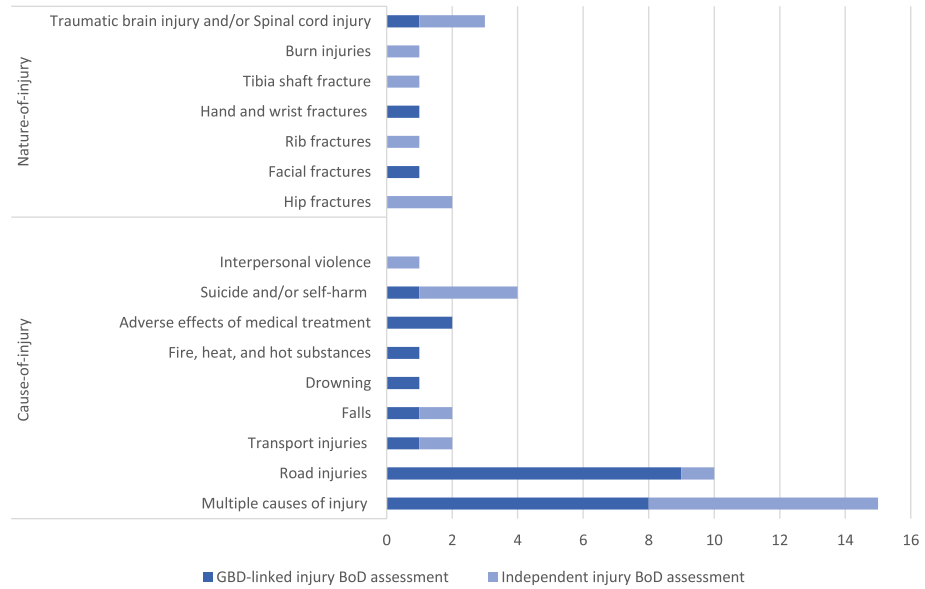


**Fig. 3** Number of GBD-linked and independent injury burden of disease studies ($n = 48$) by cause-nature of injury

calculations. Seven single-country independent injury BoD studies used GBD DWs [26, 28, 35, 39, 40, 44, 47], three used a combination of DWs [22, 23, 46], and one study applied Australian DWs [24].

### YLL methodological choices in injury burden of disease studies

#### *Choice of life table*

Most single-country independent studies have used national life tables [23, 24, 27, 33, 38–40] or national life expectancies [22, 28, 36, 66] to calculate YLLs. The remaining single-country independent BoD studies used aspirational model life tables that have a standard life expectancy at birth, such as those used in the GBD study [26, 30, 31, 33, 35, 64]. Multi-country independent studies frequently used aspirational global [43, 45–47] or European [67] life tables. The remaining single-country and multi-country GBD-linked BoD studies used the standard model life tables from GBD/WHO [1, 41, 50, 51, 53–63, 65, 68].

## Discussion

This systematic literature review has provided insights into the methodological design choices and assumption parameters that have been used to quantify the burden of injury in terms of YLL, YLD, or DALY. A total of 48 BoD studies met our inclusion criteria; more than half

**Table 2** Methodological design choices and assumption parameters in injury burden of disease studies

| Author | Year | Single- or multi-country category? | Geographic Location | Type of study | | Injury classification | | Classification of injury diagnosis | Design choices of YLL calculations | Design choices of YLD calculations | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Independent study | GBD-linked study | Cause-of-injury category | Nature-of-injury category | | | Incidence- or prevalence-based approach? | Usage of disability weights |
| Aldridge et al. [50] | 2017 | Multi-country | WHO European Region | | • | • | | ICD-9; ICD-10 | WHO standard model life tables | Prevalence | GBD DWs |
| Begg & Tomijima [60] | 2006 | Multi-country | Global | | | • | • | ICD-9; ICD-10 | GBD standard model life tables | Incidence | GBD DWs |
| Crowe et al. [52] | 2020 | Multi-country | Global | | • | • | • | ICD-9; ICD-10 | NA | Prevalence | GBD DWs |
| Dhondt et al. [23] | 2012 | Single-country | Belgium (Flanders; Brussels) | • | | • | • | ICD-9 (aggregated to the EUROCOST classification) | Belgian life table | Incidence | Empirical DWs; GBD DWs |
| Dhondt et al. [22] | 2013 | Single-country | Belgium (Flanders; Brussels) | • | | • | • | ICD-9; ICD-10 (aggregated to the EUROCOST classification) | Belgian LE | Incidence | Dutch DWs; GBD DWs |
| Fattahov & Piankova [64] | 2018 | Single-country | Russia | • | | • | | ICD-10 | GBD standard model life tables | NA | NA |
| Franklin et al. [65] | 2020 | Multi-country | Global | | • | | | ICD-9; ICD-10 | GBD standard model life tables | NA | NA |
| Gobbino et al. (on behalf of CRMSS) [24] | 2012 | Single-country | Italy (Friuli Venezia Giulia) | • | | • | • | ICD-9 | Italian life table | Incidence | Australian DWs |
| Haagsma et al. [25] | 2008 | Single-country | Netherlands | • | | • | | ICD-9 (aggregated to the EUROCOST classification) | NA | Incidence | Empirical DWs |
| Haagsma et al. [43] | 2012 | Multi-country | Netherlands; Ceres; Thailand | • | | • | | ICD-10 (aggregated to the EUROCOST classification) | Standard West 26 | Incidence | Empirical DWs |
| Haagsma et al. [1] | 2016 | Multi-country | Global | | • | • | • | ICD-9; ICD-10 | GBD standard model life tables | Prevalence | GBD DWs |
| Haagsma et al. [54] | 2020 | Multi-country | GBD Western Europe | | • | • | | ICD-9; ICD-10 | GBD standard model life tables | Prevalence | GBD DWs |
| Haagsma et al. [53] | 2020 | Multi-country | Global | | • | • | | ICD-9; ICD-10 | GBD standard model life tables | Prevalence | GBD DWs |
| Hagen et al. [26] | 2020 | Single-country | Norway | • | | | • | NR | GBD standard model life tables | Incidence | GBD DWs |
| Hoeymans & Schoemaker [38] | 2010 | Single-country | Netherlands | • | | • | • | ICD-10 | Dutch life table | Incidence | Empirical DWs |

**Table 2** (continued)

| Author | Year | Single- or multi-country category? | Geographic Location | Type of study | | Injury classification | | Classification of injury diagnosis | Design choices of YLL calculations | Design choices of YLD calculations | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Independent study | GBD-linked study | Cause-of-injury category | Nature-of-injury category | | | Incidence- or prevalence-based approach? | Usage of disability weights |
| Holtslag et al. [27] | 2008 | Single-country | Netherlands | • | | • | | NR | Dutch life table | Incidence | Empirical DWs |
| James et al. [55] | 2019 | Multi-country | Global | | • | • | • | ICD-9; ICD-10 | GBD standard model life tables | Prevalence | GBD DWs |
| James et al. [11] | 2019 | Multi-country | Global | | • | • | • | ICD-9; ICD-10 | NA | Prevalence | GBD DWs |
| James et al. [56] | 2020 | Multi-country | Global | | • | • | • | ICD-9; ICD-10 | NA | Prevalence | GBD DWs |
| Johnell & Kanis [44] | 2004 | Multi-country | World Bank Regions | • | | | • | NR | NR | Incidence | GBD DWs |
| Khan et al. [57] | 2020 | Multi-country | Global | | • | • | | ICD-9; ICD-10 | GBD standard model life tables | Prevalence | GBD DWs |
| Lalloo et al. [58] | 2020 | Multi-country | Global | | • | • | • | ICD-9; ICD-10 | GBD standard model life tables | Prevalence | GBD DWs |
| Lapostolle et al. [28] | 2009 | Single-country | France | • | | • | • | ICD-10 (AIS codes) | French LE | Incidence | GBD DWs |
| Leliveld et al. [29] | 2020 | Single-country | Netherlands | • | | | • | ICD-9; ICD-10 | NA | Incidence | Empirical DWs |
| Lin [59] | 2016 | Multi-country | Global | | • | • | | NR | GBD standard model life tables | Prevalence | GBD DWs |
| Lukaschek et al. [66] | 2012 | Single-country | Germany | • | | • | | ICD-10 | German LE | NA | NA |
| Lunevicius & Haagsma [41] | 2018 | Single-country | England (9 English Regions) | | • | • | | ICD-9; ICD-10 | GBD standard model life tables | Prevalence | GBD DWs |
| Lyons et al. [45] | 2017 | Multi-country | EU-28 | • | | • | • | ICD-10 | GBD standard model life tables | Incidence | Empirical DWs |
| Majdan et al. [67] | 2017 | Multi-country | EU-16 | • | | • | • | ICD-10 | European Union life table | NA | NA |
| Naghavi et al. [68] | 2019 | Multi-country | Global | | • | • | | ICD-9; ICD-10 | GBD standard model life tables | NA | NA |
| NHS Health Scotland [39] | 2016 | Single-country | Scotland | • | | • | • | ICD-10 | Scottish life table | Prevalence | GBD DWs |
| NHS Health Scotland [40] | 2016 | Single-country | Scotland | • | | • | • | ICD-10 | Scottish life table | Prevalence | GBD DWs |
| Peden et al. [61] | 2002 | Multi-country | Global | | • | • | • | ICD-9; ICD-10 | GBD standard model life tables | Incidence | GBD DWs |

**Table 2** (continued)

| Author | Year | Single- or multi-country category? | Geographic Location | Type of study | | Injury classification | | Classification of injury diagnosis | Design choices of YLL calculations | Design choices of YLD calculations | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Independent study | GBD-linked study | Cause-of-injury category | Nature-of-injury category | | | Incidence- or prevalence-based approach? | Usage of disability weights |
| Polinder et al. [47] | 2007 | Multi-country | Austria; Denmark; UK (England & Wales); Ireland; Norway; Netherlands | • | | • | • | ICD-9; ICD-10 | GBD standard model life tables | Incidence | GBD DWs |
| Polinder et al. [46] | 2010 | Multi-country | Austria; Latvia; Denmark; UK (England & Wales); Ireland; Netherlands; Norway; Slovenia | • | | • | • | ICD-9; ICD-10 | GBD standard model life tables | Incidence | GBD DWs; Empirical DWs |
| Polinder et al. [31] | 2012 | Single-country | Netherlands | • | | • | | ICD-9 (aggregated to the EUROCOST classification) | GBD standard model life tables | Incidence | Empirical DWs |
| Polinder et al. [30] | 2015 | Single-country | Netherlands | • | | • | | ICD-9 (MAIS code; aggregated to the EUROCOST classification) | GBD standard model life tables | Incidence | Empirical DWs |
| Prins et al. [32] | 2021 | Single-country | Netherlands | • | | | • | NA | NA | Incidence | Empirical DWs |
| Scholten et al. [33] | 2014 | Single-country | Netherlands | • | | | • | ICD-9 | GBD standard model life tables | Incidence | Empirical DWs |
| Snijders et al. [34] | 2016 | Single-country | Netherlands | • | | • | • | ICD-9 | Dutch life table | Incidence | Empirical DWs |
| Sethi et al. [62] | 2008 | Multi-country | WHO European Region | | • | • | | ICD-9; ICD-10 | GBD standard model life tables | Incidence | GBD DWs |
| Spronk et al. [48] | 2020 | Multi-country | Netherlands; New Zealand; Australia | • | | | • | NA | NA | Incidence | Empirical DWs |
| Tainio et al. [35] | 2014 | Single-country | Sweden | • | | • | • | ICD-9; ICD-10 (AIS code) | GBD standard model life tables | Incidence | GBD DWs |
| Tainio [42] | 2015 | Single-country | Poland | | • | • | | NR | NR | Polish data on traffic fatalities and GBD 2010 data | NR |

**Table 2** (continued)

| Author | Year | Single- or multi-country category? | Geographic Location | Type of study | | Injury classification | | Classification of injury diagnosis | Design choices of YLL calculations | Design choices of YLD calculations | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Independent study | GBD-linked study | Cause-of-injury category | Nature-of-injury category | | | Incidence- or prevalence-based approach? | Usage of disability weights |
| Twisk et al. [36] | 2017 | Single-country | Netherlands | • | | • | | ICD-9 (aggregated to the EUROCOST classification) | Dutch LE | Incidence | Empirical DWs |
| Valent et al. [63] | 2004 | Multi-country | WHO European Region | | • | • | | ICD-9; ICD-10 | GBD standard model life tables | Incidence | GBD DWs |
| Weijermars et al. [37] | 2016 | Single-country | Netherlands | • | | • | | ICD-9 (aggregated to the EUROCOST classification) | NA | Incidence | Empirical DWs |
| Weijermarset al. [49] | 2018 | Multi-country | Austria; Spain; Belgium; France; England; Netherlands | • | | • | • | ICD-9; ICD-10; aggregated to the EUROCOST classification) | NA | Incidence | Empirical DWs |

*AIS* Abbreviated Injury Scale, *BoD* Burden of Disease, *CRMSS* Centro regionale di monitoraggio della sicurezza stradale, *DALY* Disability-Adjusted Life Years, *DW* Disability Weight, *EUROCOST* EUROCOST classification of injuries, *GBD* Global Burden of Disease, *ICD* International Classification of Diseases, *LE* Life Expectancy, *MAIS* Maximum Abbreviated Injury Scale, *NA* Not Applicable, *NR* Not Reported, *UK* United Kingdom, *YLD* Years-Lived with Disability, *YLL* Years of Life Lost due to premature mortality, *WHO* World Health Organization

being single-country or multi-country independent studies, while the remaining were GBD-linked studies. Considerable methodological variation across injury BoD studies was observed; differences were mainly apparent in the design choices or assumption parameters towards injury YLD calculations, implementation of DWs, and the choice of life table for YLL calculations.

First, considerable heterogeneity exists in the aggregation level of cause-of-injury and nature-of-injury categories (see Fig. 3) that were used in the calculations and reporting of burden of injury studies. Among the unintentional injury-specific assessments, we observed a high number of falls-related BoD studies and no injury disease burden assessments at all related to exposure to mechanical forces, poisonings, or foreign body and animal contact. Moreover, there was diversity in the cause-of-injury and nature-of-injury categories reported. Most studies calculated DALYs for multiple causes-of-injury, yet there were also several studies that were limited to one specific nature-of-injury category, such as traumatic brain injury, or cause-of-injury category, such as road injury.

The high percentage of studies quantifying the burden of road injury has enhanced the visibility of road injury in Europe and shown that (injury) BoD assessments can, in turn, inform health policy and measures. Burden of road injury studies can be used to monitor the possible effect of improvements in car safety technologies, road infrastructure, better compliance with speed limits or seatbelt or helmet use, as observed across most European countries [69, 70]. For instance, there significant decline in road injury mortality and DALY rates across the European sub-regions over the 2000–2019 period [71].

Another striking finding of our systematic review was that studies that reported on nature-of-injury DALYs were more often independent studies than GBD-linked ones. A possible explanation for this finding may be that nature-of-injury DALYs were available from the GBD 2013 study onwards [72]. Before that, only cause-of-injury DALYs were available from the GBD results tool. The burden of injury studies that were limited to one specific cause-of-injury were focused on those causes-of-injury that are listed in the top 10 ranking of injury DALYs in Europe [55].

Second, our review reveals that most independent injury BoD studies (78%) were performed in Western European countries, while the number of injury disease burden studies across Central and Eastern European countries was limited. A possible explanation for this difference may be the lack of appropriate data sources, harmonization of data collection processes, a decentralized system of records access and poor-quality checks in the Central and Eastern European region compared to the Western European region. A second explanation may be that the use of these health metrics as indicators of health status may not be valued as important in these countries and their health reporting systems. This issue, in combination with the lack of resources, capacity or expertise in the use of these BoD metrics, contribute further to the chasm between data availability, data quality checking and subsequent data use for such large-scale national disease data estimation studies. Also, a variety of injury preventive interventions and/or policies has been developed in many Western European countries [73, 74]. Hence, many of the injury premature deaths and disabilities occur in Central and Eastern Europe [17], where fewer countries had developed national policies for injury prevention [74–76]. Future injury BoD assessments may be important in facilitating decision-making processes for injury policy formulation in these European regions.

Third, while most of injury BoD studies used the ICD coding system to classify injuries, we found that some independent BoD studies classified injury consequences based on the 39 injury-diagnoses of the EUROCOST system [21]. This classification system was developed for assessments of the cost of illness of injury [21, 77, 78] and may be less appropriate for injury DALY calculations due to nature-of-injury groupings encompassing injuries that vary widely in severity and duration. Significantly, some single-country independent studies did not report the injury diagnosis coding system or the methods that were used to deal with inaccurately coded injury deaths. This highlights the need for development and use of guidelines for performing and reporting of injury BoD studies.

Fourth, we found that most independent BoD studies used the incidence-based approach to estimate injury YLDs. This is at odds with the GBD approach (i.e., prevalence-based), which applies a meta-regression tool (DisMod-MR) to stream out (long-term) prevalence for each combination of cause-of-injury and nature-of-injury from incidence, by assuming a steady state where rates are consistently stable over time [11, 17]. The choice of incidence *versus* prevalence approach should be dictated by the pre-defined goals and application of the study. For instance, when assessing the burden of injury in terms of DALY and its components and planning, implementing or evaluating preventive strategies, an incidence-based approach should be used, whereas for health services planning purposes, a prevalence-based approach might be more appropriate.

Fifth, most single-country independent injury BoD studies used national life tables to calculate YLLs. The choice between national and global aspirational life-table is dependent on the study scope [15]. Aspirational life-tables ensure internationally comparable results since they are based on the same population

structure, while national life-tables preclude the possibility of cross-country comparisons.

Furthermore, we observed that some injury BoD studies did not report the life-table that had been used to calculate YLLs. This suggests a need for improvements in the reporting of future injury disease burden studies, as the choice of national or aspirational life-table is crucial when performing a BoD assessment; evidence has illustrated the impact of how ranking of causes is affected [79]. The use of standardized reporting guidelines in DALY calculation studies would enhance comparability of results, communication among BoD researchers and/or policy makers, as well as facilitate quality assessments of the disease burden studies.

Lastly, a crucial methodological step in causes-of-death analysis is the estimation of total all-cause mortality (also referred to as mortality envelope) by each age and sex strata, for correcting death under-counting or over-counting using either redistribution methods and/or regression techniques etc. Although insight into this methodological step was beyond the scope of our systematic literature review, future studies should investigate whether mortality envelopes are used in disease burden studies, and if they are used, which methods are applied to construct them.

### Strengths and limitations of the study

This systematic literature review may be limited by the nature of the grey literature searched and the national public health websites targeted. Although we have used a variety of literature databases and search engines, some BoD studies may have been missed. However, it is possible that other BoD studies estimating the burden of injuries have been conducted but not published or documented. Despite these limitations, our systematic literature review provides the first of its kind in bringing together existing injury-specific BoD studies undertaken in Europe. We comprehensively reviewed the methodological design choices and assumption parameters that have been made to calculate YLL, YLD, and DALY in these European studies since the 1990s. Finally, we sought to provide recommendations with regard to the application and reporting of (injury) YLL and YLD design choices.

## Conclusions

In this systematic literature review we examined independent and GBD-linked studies that assessed the burden caused by injury, in European Region countries. Considerable methodological variation across injury BoD assessments was observed; differences were mainly apparent in the design choices or assumption parameters towards injury YLD calculations, implementation of DWs, and the choice of life table for YLL calculations. Development and use of guidelines for performing and reporting of BoD studies is crucial to enhance transparency and comparability of injury BoD estimates across Europe and beyond.

#### Abbreviations

BoD: Burden of Disease; DALY: Disability-adjusted life years; DW: Disability Weight; GBD: Global Burden of Disease; ICD: International Classification of Diseases; YLD: Years lived with disability; YLL: Years of life lost.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-022-13925-z.

**Additional file 1.** Search strategy and grey literature search and overview of studies.

**Additional file 2.** Data extraction form.

#### Acknowledgements

The authors wish to thank Maarten Engel from the Erasmus MC Medical Library for developing and updating the search strategies. The authors would also like to acknowledge the networking support from COST Action CA18218 (European Burden of Disease Network; www.burden-eu.net), supported by COST (European Cooperation in Science and Technology; www.cost.eu).

#### Authors' contributions

PC and EP performed the data extractions for English studies. VG, EvdL, JI, HN, IN, AM, and RS performed the data extractions for the non-English studies. PC, SP, and JH analyzed and interpreted the data. PC wrote the initial draft of the paper. PC, EP, VG, EvdL, BD, SP, DP, JI, HN, IN, AM, RS, MM, BA, AA, CLS, BC, BC, SC, KD, ME, FF, AF, CGJM, FG, AG, HG, PH, GI, LSJ, ZK, KKS, AKN, NMK, CL, BL, AL, MM, EM, AM, LM, SM, JNM, EN, ESWN, VN, IAN, RC, PP, VP, MRN, SR, HS, JVS, CMAS, MSM, DS, ACS, NS, FT, BU, HBU, FGV, OV, MV, FSV, GW, SP, and JH made critical revisions and provided intellectual content to the manuscript, approved the final version to be published, and agreed to be accountable for all aspects of this work.

#### Funding

No funding was received for this study.

#### Availability of data and materials

All data generated or analyzed during this study are publicly available at the cited links, and also at the Appendices.

## Declarations

#### Ethics approval and consent to participate

Not applicable.

#### Consent for publication

Not applicable.

#### Competing interests

None declared.

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Received: 5 April 2022 Accepted: 1 August 2022
Published online: 17 August 2022

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