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Periklis Charalampous

Juanita A. Haagsma

Filippo Ariani

Anne Gallay

Kim Moesgaard Iburg

See next page for additional authors

Authors

Periklis Charalampous, Juanita A. Haagsma, Filippo Ariani, Anne Gallay, Kim Moesgaard Iburg, Evangelia Nena, Che Henry Ngwa, Alexander Rommel, Ausra Zelviene, and Manasi Kumar

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Periklis Charalampous (p.charalampous@erasmusmc.nl)
Erasmus MC https://orcid.org/0000-0002-3460-4828

Juanita A. Haagsma
Erasmus MC

Filippo Ariani
Azienda USL Toscana centro

Anne Gallay
Santé publique France: Sante publique France

Kim Moesgaard Iburg
Aarhus University: Aarhus Universitet

Evangelia Nena
Democritus University of Thrace: Demokriteio Panepistemio Thrakes

Che Henry Ngwa
University of Gothenburg: Goteborgs Universitet

Alexander Rommel
Robert Koch Institute: Robert Koch Institut

Ausra Zelviene
Institute of Hygiene

Kedir Hussein Abegaz
Cyprus Near East University: Yakin Dogu Universitesi

Hanadi Al Hamad
Hamad Medical Corporation

Luciana Albano
University of Campania Luigi Vanvitelli: Universita degli Studi della Campania Luigi Vanvitelli

Catalina Liliana Andrei
Carol Davila University of Medicine and Pharmacy: Universitatea de Medicina si Farmacie Carol Davila

Tudorel Andrei
Bucharest University of Economic Studies: Academia de Studii Economice din Bucuresti

Ippazio Cosimo Antonazzo
University of Milan–Bicocca: Universita degli Studi di Milano-Bicocca

Olatunde Aremu
Birmingham City University - City North Campus: Birmingham City University
Ashokan Arumugam
University of Sharjah
Alok Atreya
Lumbini Medical College
Avinash Aujayeb
Northumbria HealthCare NHS Trust: Northumbria Healthcare NHS Foundation Trust
Jose Luis Ayuso-Mateos
Carlos III Health Institute: Instituto de Salud Carlos III
Luchuo Engelbert Bain
University of Lincoln - Brayford Campus: University of Lincoln
Maciej Banach
Medical University of Lodz: Uniwersytet Medyczny w Lodzi
Till Winfried Bärnighausen
Heidelberg University
Francesco Barone-Adesi
University of Eastern Piedmont: Universita degli Studi del Piemonte Orientale Amedeo Avogadro
Massimiliano Beghi
AUSL della Romagna: Azienda Unita Sanitaria Locale della Romagna
Derrick A. Bennett
University of Oxford Department of Public Health: University of Oxford Nuffield Department of Population Health
Akshaya S. Bhagavathula
United Arab Emirates University
Félix Carvalho
University of Porto: Universidade Do Porto
Giulio Castelpietra
Health Care Authority Friuli Occidentale: Azienda Sanitaria Friuli Occidentale
Ledda Caterina
University of Catania: Universita degli Studi di Catania
Joht Singh Chandan
University of Birmingham
Rosa A.S. Couto
University of Porto: Universidade Do Porto
Natália Cruz-Martins
University of Porto Faculty of Medicine: Universidade do Porto Faculdade de Medicina
Giovanni Damiani
IRCCS Galeazzi Orthopaedic Institute: IRCCS Istituto Ortopedico Galeazzi

Anna Dastiridou
General University Hospital of Larissa: Panepistemiako Geniko Nosokomeio Larisas
Andreas K. Demetriades
Royal Infirmary of Edinburgh
Diana Dias-da-Silva
University of Porto: Universidade Do Porto
Adeniyi Francis Fagbamigbe
University of Ibadan
Seyed-Mohammad Fereshtehnejad
University of Ottawa
Eduarda Fernandes
University of Porto: Universidade Do Porto
Pietro Ferrara
University of Milan–Bicocca: Universita degli Studi di Milano-Bicocca
Florian Fischer
Charite Universitatsmedizin Berlin Campus Charite Mitte: Charite Universitatsmedizin Berlin
Urbano Fra.Paleo
University of Extremadura: Universidad de Extremadura
Silvia Ghirini
Istituto Superiore di Sanità: Istituto Superiore Di Sanita
James C. Glasbey
University of Birmingham
Ionela-Roxana Glavan
Bucharest University of Economic Studies: Academia de Studii Economice din Bucuresti
Nelson G.M. Gomes
University of Porto: Universidade Do Porto
Michal Grivna
United Arab Emirates University
Netanja I. Harlianto
Utrecht University: Universiteit Utrecht
Josep Maria Haro
CIBERSAM: Centro de Investigacion Biomedica en Red de Salud Mental
M. Tasdik Hasan
University of Liverpool
Sorin Hostiuc
Carol Davila University of Medicine and Pharmacy: Universitatea de Medicina si Farmacie Carol Davila
Ivo Iavicoli
University of Naples Federico II: Universita degli Studi di Napoli Federico II
Milena D. Ilic

University of Porto: Universidade Do Porto

Raimundas Lunevicius

University of Liverpool

Aurea Madureira-Carvalho

University of Porto: Universidade Do Porto

Enkeleint A. Mechili

University of Crete: Panepistemio Kretes

Azeem Majeed

Imperial College London

Ritesh G. Menezes

Imam Abdulrahman Bin Faisal University

Alexios-Fotios A. Mentis

Hellenic Pasteur Institute

Atte Meretoja

Melbourne School of Health Sciences: The University of Melbourne Melbourne School of Health Sciences

Tomislav Mestrovic

Veleuciliste u Varazdinu

Tomasz Miazgowski

Pomeranian Medical University in Szczecin: Pomorski Uniwersytet Medyczny w Szczecinie

Bartosz Miazgowski

Pomeranian Medical University: Pomorski Uniwersytet Medyczny w Szczecinie

Andreea Mirica

Bucharest University of Economic Studies: Academia de Studii Economice din Bucuresti

Mariam Molokhia

King's College London

Shafiu Mohammed

Ahmadu Bello University

Lorenzo Monasta

Burlo Garofalo Institute for Maternal and Child Health Scientific Library: IRCCS materno infantile Burlo Garofolo Biblioteca Scientifica

Francesk Mulita

University General Hospital of Patras: Panepistemiako Geniko Nosokomeio Patron Panagia e Boetheia

Mukhammad David Naimzada

Kursk State Medical University: Kurskij Gosudarstvennyj Medicinskij Universitet

Ionut Negoi

Carol Davila University of Medicine and Pharmacy: Universitatea de Medicina si Farmacie Carol Davila

Subas Neupane

Tampereen Yliopisto

Bogdan Oancea
University of Bucharest: Universitatea din Bucuresti
Hans Orru
Umea University: Umea Universitet
Adrian Otoiu
Bucharest University of Economic Studies: Academia de Studii Economice din Bucuresti
Nikita Otstavnov
Moscow Institute of Physics and Technology: Moskovskij fiziko-tehniceskij institut nacional'nyj issledovatel'skij universitet
Stanislav S. Otstavnov
Moscow Institute of Physics and Technology: Moskovskij fiziko-tehniceskij institut nacional'nyj issledovatel'skij universitet
Alicia Padron-Monedero
Carlos III Health Institute: Instituto de Salud Carlos III
Songhomitra Panda-Jonas
Heidelberg University
Shahina Pardhan
Anglia Ruskin University
Jay Patel
University of Leeds
Paolo Pedersini
: Fondazione Don Carlo Gnocchi
Marina Pinheiro
University of Porto: Universidade Do Porto
Ivo Rakovac
World Health Organization Regional Office for Europe
Chythra R. Rao
Manipal Academy of Higher Education
Salman Rawaf
Public Health England
David Laith Rawaf
University College London
Violet Rodrigues
Abbeyleix Community Nursing Unit
Luca Ronfani
Burlo Garofalo Institute for Maternal and Child Health Scientific Library: IRCCS materno infantile Burlo Garofolo Biblioteca Scientifica
Dominic Sagoe
University of Bergen: Universitetet i Bergen

Francesco Sanmarchi
University of Bologna: Universita degli Studi di Bologna
Milena M. Santric-Milicevic
University of Belgrade: Univerzitet u Beogradu
Brijesh Sathian
Bournemouth University
Aziz Sheikh
University of Edinburgh: Centre of Medical Informatics
Rahman Shiri
Finnish Institute of Occupational Health: Tyoterveyslaitos
Siddharudha Shivalli
London School of Hygiene & Tropical Medicine
Inga Dora Sigfusdottir
Reykjavik University: Haskolinn i Reykjavik
Rannveig Sigurvinsdottir
Reykjavik University: Haskolinn i Reykjavik
Valentin Yurievich Skryabin
Moscow Research and Practical Centre on Addictions
Anna Aleksandrovna Skryabina
Balashiha Central Hospiral
Catalin-Gabriel Smarandache
Carol Davila University of Medicine and Pharmacy: Universitatea de Medicina si Farmacie Carol Davila
Bogdan Socea
Carol Davila University of Medicine and Pharmacy: Universitatea de Medicina si Farmacie Carol Davila
Raúl A.R.C. Sousa
Professional Association of Licensed Optometry Professionals
Paschalis Steiropoulos
Democritus University of Thrace: Demokriteio Panepistemio Thrakes
Rafael Tabarés-Seisdedos
University of Valencia: Universitat de Valencia
Marcos Roberto Tovani-Palone
University of Sao Paulo: Universidade de Sao Paulo
Fimka Tozija
Saints Cyril and Methodius University in Skopje
Sarah Van de Velde
University of Antwerp: Universiteit Antwerpen
Tommi Juhani Vasankari
UKK-instituutti
Massimiliano Veroux

University of Catania: Universita degli Studi di Catania

Francesco S. Violante

University of Bologna: Universita degli Studi di Bologna

Vasiliy Vlassov

National Research University Higher School of Economics: Nacional'nyj issledovatel'skij universitet Vyssaa skola ekonomiki

Yanzhong Wang

King's College London

Ali Yadollahpour

: The University of Sheffield Department of Psychology

Sanni Yaya

University of Ottawa

Mikhail Sergeevich Zastrozhin

Moscow Research and Practical Centre on Addictions

Anasthasia Zastrozhina

Russian Medical Academy of Continuing Professional Education: Rossijskaa medicinskaa akademia nepreryvnogo professional'nogo obrazovania

Suzanne Polinder

Erasmus MC

Marek Majdan

Trnavska Univerzita v Trnave

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Abstract

Background: Injury remains a major concern to public health in the European region, particularly among adults younger than 49 years. Previous iterations of the Global Burden of Disease (GBD) study showed wide variation in injury death and disability adjusted life year (DALY) rates across Europe, indicating injury inequality gaps between sub-regions and countries. The objectives of this study were to: 1) compare GBD 2019 estimates on injury mortality and DALYs across European sub-regions and countries by cause-of-injury category and sex; 2) examine changes in injury DALY rates over a 20 year-period by cause-of-injury category, sub-region and country; and 3) assess inequalities in injury mortality and DALY rates across the countries.

Methods: We performed a secondary database descriptive study using the GBD 2019 results on injuries in 44 European countries from 2000 to 2019. Inequality in DALY rates between these countries was assessed by calculating the DALY rate ratio between the highest-ranking country and lowest-ranking country in each year.

Results: In 2019, in Eastern Europe 80 [95% uncertainty interval (UI): 71 to 89] people per 100,000 died from injuries; twice as high compared to Central Europe (38 injury deaths per 100,000; 95% UI 34 to 42) and three times as high compared to Western Europe (27 injury deaths per 100,000; 95%UI 25 to 28). The injury DALY rates showed less pronounced differences between Eastern (5129 DALYs per 100,000; 95% UI: 4547 to 5864), Central (2940 DALYs per 100,000; 95% UI: 2452 to 3546) and Western Europe (1782 DALYs per 100,000; 95% UI: 1523 to 2115). Injury DALY rate was lowest in Italy (1489 DALYs per 100,000) and highest in Ukraine (5553 DALYs per 100,000). The difference in injury DALY rates by country was larger for males compared to females. The DALY rate ratio was highest in 2005, with DALY rate in the lowest-ranking country (Russian Federation) 6.0 times higher compared to the highest-ranking country (Malta). After 2005, the DALY rate ratio between the lowest- and the highest-ranking country gradually decreased to 3.7 in 2019.

Conclusions: Injury death and DALY rates were highest in Eastern Europe and lowest in Western Europe, although differences in injury DALY rates decline rapidly, particularly in the past decade. The injury DALY rate ratio of highest- and lowest-ranking country declined from 2005 onwards, indicating declining inequalities in injuries between European countries.

Background

Injuries are recognized as a major concern in public health worldwide. Results of the Global Burden of Disease (GBD) study showed that globally in 2019, 8% of all deaths were due to injury [1]. In the European region, the share of injury deaths was 5% [2]; however, major differences across European countries are observed, ranging from a low of 3% in Bulgaria to a high of 8% in Russia.

Apart from a major cause of death, injury is also often cited as an important cause of disability. Cohort studies among trauma patients showed that the majority of trauma patients had lower health-related

quality of life scores one year after sustaining the injury, compared to their pre-injury health status or the general population [3, 4]. Only a share of patients with long-term consequences of injury will recover, whereas most will experience permanent disabilities [5–7]. These findings highlight the importance of including both fatal and non-fatal consequences of injury, when describing the population health impact of injury.

A widely used population health metric that incorporates the years of life lost due to premature mortality (YLL) and years lived with disability (YLD) is the disability adjusted life year (DALY) [8]. This composite measure allows comparison of the population health impact of diseases and injuries with varying incidence and case fatality rates. By calculating age-standardized DALY rates, the DALYs are adjusted for differences in age structure and size of the populations. Hence, population health impact of different causes of disease and injury can be compared across countries and over time.

Comparisons of the population health impact of different causes of injury are crucial for the identification of major causes of injury and injury DALY trends over time, which may serve as input for priority-setting with regards to national injury prevention measures and their effects and health service planning [9]. Moreover, comparison of injury DALY rates may help to identify the existence of health inequality gaps between countries. Health inequality gaps are unfair differences in health status between sub-groups of a population that are avoidable [10]. A recently published systematic review on inequalities in injuries in the European region identified two cross-country studies that investigated inequalities over time [11]. Both studies were limited to children aged 1 to 14 years and used mortality rate ratios to investigate inequalities in injuries, instead of an integrative measure that includes both fatal and non-fatal outcomes, such as the DALY [12, 13]. Insight into health inequalities in injuries across countries, using the DALY metric and within total population is currently lacking in Europe.

Therefore, the objectives of this study were to: 1) compare the GBD 2019 estimates on injury mortality and DALYs across 44 countries of the GBD European region (i.e., Central, Eastern, and Western Europe) by cause-of-injury category and sex; 2) examine changes in injury DALY over a 20 year-period by cause-of-injury category, sub-region and country; and 3) assess inequalities in injury mortality and DALY rates across Central, Eastern, and Western European countries.

Methods

We analyzed levels and trends of incidence, mortality, and DALY and its components: YLL and YLD of injury in the European region of the GBD 2019 study. The DALY is calculated by adding YLLs and YLDs. YLLs are calculated by multiplying deaths by the remaining life expectancy at the age of death. YLDs are calculated by multiplying the number of cases with a certain health outcome with the disability weight assigned to this health outcome. One DALY is equivalent to one healthy life year lost from mortality and disability.

The GBD 2019 study provided global and regional estimates for 286 causes of death, 369 diseases and injuries, for 23 age groups, male and female sex, and for 204 countries and territories from 1990 to 2019

[1]. Detailed descriptions of the methodology and approach of the GBD study and supplemental information on methods that were used to calculate incidence, mortality, YLL, YLD and DALY estimates have been published elsewhere [1, 14]. For the present study, we used the GBD 2019 interactive data visualization tool 'GBD Compare' to retrieve the estimates for injury incidence, mortality, YLLs, YLDs, and DALYs (GBD 2019 Results. Seattle, United States: Institute for Health Metrics and Evaluation (IHME), 2019; http://vizhub.healthdata.org/gbd-compare/). In our study, we used estimates for each year in the period between 1990 and 2019. We compared incidence, mortality, YLL, YLD, and DALY by sex, country and over time.

Cause-of-injury categories

Injury incidence and mortality data, coded according to the International Classification of Diseases, Ninth Revision (ICD-9) and the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10), were categorized into mutually exclusive and collectively exhaustive GBD cause-of-injury categories [14]. The cause-of-injury categories covered by the GBD were arranged in standard hierarchical categories of four levels. Level 1 causes consist of the category "Injuries" (Group III). This level can be broken down into three Level 2 cause-of-injury classifications, namely "Unintentional injury", "Transport injury" and "Self-harm and interpersonal violence". These level 2 causes can be further broken down into seventeen Level 3 and twenty-four Level 4 cause-of-injury categories. The Level 4 cause-of-injury categories convey the most detail about the causes of injury. For example, the Level 2 cause-of-injury category "Self-harm and interpersonal violence" is subdivided into Level 3 cause-of-injury categories "Self-harm" and "Interpersonal violence". The Level 3 cause-of injury-category "Interpersonal violence" can be broken down into four Level 4 categories "Psychical violence by firearm", "Psychical violence by sharp object", "Psychical violence by other means" and "Sexual violence". The case definitions and ICD-codes of each of the cause-of-injury categories used in the GBD 2019 study can be found elsewhere [1, 14]. For the present analysis, we report the Level 3 cause-of-injury categories. Injury incidence was restricted to cases warranting some form of healthcare, including General Practitioner and Emergency Department visits, in a healthcare system, where patients have full, unrestricted access to healthcare.

Selection of countries

In GBD 2019, Europe is divided into three regions: the Central European region (13 countries), the Eastern European region (7 countries) and the Western European region (24 countries). Thirteen countries were included in the Central European region of the GBD: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Hungary, North Macedonia, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia. Seven countries were included in the Eastern European region of the GBD: Belarus, Estonia, Latvia, Lithuania, Republic of Moldova, Russian Federation and Ukraine. Twenty-four countries were included in the Western European region of the GBD: Andorra, Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Malta, Monaco, Netherlands, Norway, Portugal, San Marino, Spain, Sweden, Switzerland and United Kingdom.

Percent change

The percent change over the time 2000-2019 period is calculated by subtracting the 2000 DALY estimate for a specific cause-of-injury and population from the 2019 DALY estimate for that specific cause-of-injury and population and dividing it by the 2000 DALY estimate for that specific cause-of-injury and population. A positive change indicates an increase of the burden resulting from that specific cause-of-injury during the 20-year study period, whereas a negative change a decrease.

Assessment of inequality in mortality and DALY rates

Inequality in mortality rate between these 44 countries was calculated using the ratio of mortality rate for the highest-ranking country according to injury mortality rates to lowest-ranking country in each year. Inequality in DALY rate between countries was calculated by using the ratio of DALY rate for the highest-ranking country according to injury DALY rates to lowest-ranking country in each year.

Uncertainty

The GBD estimates have varying degrees of uncertainty in the input data, the data adjustments, and the statistical models used to estimate values for all geographical locations over time [14]. Standard GBD methodology is that for each outcome variable (incidence, mortality, YLL, YLD, and DALY), uncertainty from each source is propagated at the level of 1000 draws; that is, all estimates were calculated 1000 times, each time drawing from the posterior distributions. In the Results section, we present the median value of the 1000 draws of the sampled incidence, mortality, YLL, YLD, and DALY values. We also present the 95% uncertainty interval (UI), which corresponds to the 2.5th and 97.5th percentiles of the corresponding distribution.

Results

Age-standardized incidence rates of injuries by European sub-region, 2019

Table 1 shows the incidence and death rates by all causes of injury and by European sub-region. The age-standardized incidence rates per 100,000 varied between Central, Eastern, and Western Europe. In 2019 in Central Europe, we observed 22,527 (95% UI: 20,338 to 24,899) new cases per 100,000, while incidence rates of all causes of injury in Eastern and Western Europe were 18,983 (95% UI: 17,295 to 20,784) and 12,313 (95%UI 11,049 to 13,739) per 100,000, respectively. Between 2000 and 2019, the change in incidence rates for all injuries has been decreased only by -3.3% (Central Europe) and -3.5% (Western Europe), and by -18.9% in Eastern Europe. However, over the same period, falls and exposure to mechanical forces tend to be the highest incident causes of injury across all the European regions.

Table 1
Incidence and death rates by cause of injury (Level 3) and by European sub-region with 95% uncertainty interval, 2019

	Death rate (per 100,000)			Incidence rate (per 100,000)		
Cause of injury	Central Europe	Eastern Europe	Western Europe	Central Europe	Eastern Europe	Western Europe
All causes of injury	37.9 (33.5 – 42.4)	80.1 (71.4 – 89.2)	26.7 (25.0 – 28.0)	22527.5 (20338.1 – 24899.4)	18983.2 (17294.7 – 20783.7)	12313 (11049.4 – 13738.9)
Road injuries	7.9 (7.0 – 9.0)	13.3 (11.9 – 15)	4.9 (4.7 – 5.1)	1901 (1632 – 2194)	2600 (2123 – 3143)	522 (447 – 612)
Other transport injuries	1.1 (1.0 – 1.2)	1.4 (1.2 – 1.6)	0.5 (0.5 – 0.6)	52.2 (40.1 – 67.0)	53.4 (40.9 – 69.4)	35.7 (27.7 – 46.5)
Falls	8.0 (7.0 – 9.0)	6.40 (5.8 – 7.1)	7.4 (6.5 – 7.9)	6674.5 (5642.8 – 7824.9)	6026.2 (5047.2 – 7185.2)	5841.7 (4886.3 – 6998.5)
Drowning	1.7 (1.5 – 2.0)	5.1 (4.6 – 5.7)	0.65 (0.6 – 0.7)	12.5 (10.5 – 15.1)	15.8 (13.1 – 19.0)	5.5 (4.5 – 6.6)
Fire, heat, and hot substances	0.9 (0.8 – 1.0)	3.5 (3.1 – 3.9)	0.4 (0.4 – 0.5)	302.0 (227.6 – 375.7)	258.0 (195.0 – 324.3)	164.9 (122.2 – 208.1)
Poisonings	0.5 (0.5 – 0.5)	3.08 (2.7 – 3.4)	0.15 (0.14 – 0.15)	151.5 (110.2 – 203.5)	128.5 (95.1 – 170.3)	73.8 (54.5 – 96.9)
Exposure to mechanical forces	0.8 (0.7 – 0.9)	1.7 (1.5 – 1.9)	0.4 (0.4 – 0.4)	8863.7 (6999.5 – 10903.4)	5198.7 (4121.1 – 6310.7)	2841.4 (2155.9 – 3547.8)
Adverse effects of medical treatment	0.7 (0.5 – 0.8)	0.7 (0.5 – 0.9)	1.0 (0.9 – 1.1)	333.9 (271.1 – 403.2)	241.5 (195.2 – 296.4)	205.8 (169.1 – 251.6)
Animal contact	0.09 (0.08 – 0.1)	0.14 (0.12 – 0.16)	0.04 (0.04 – 0.04)	916.0 (695.6 – 1250.8)	716.4 (543.5 – 979.6)	275.8 (207.7 – 381.0)
Foreign body	1.5 (1.3 – 1.7)	3.5 (3.1 – 3.9)	1.3 (1.2 – 1.4)	924.6 (758.8 – 1151.5)	1042.1 (846.1 – 1310.5)	674.8 (555.7 – 832.4)
Other unintentional injuries	0.7 (0.6 – 0.8)	1.8 (1.6 – 2.0)	0.2 (0.2 – 0.2)	1741.3 (1362.0 – 2166.2)	1481.4 (1170.8 – 1829.2)	1245.7 (957.5 – 1573.1)

	Death rate (per 100,000)			Incidence rate (per 100,000)		
Self-harm	11.5 (10.0 – 13.2)	23.05 (20.2 – 26.9)	8.5 (8.1 – 8.9)	80.8 (71.9 – 90.9)	161.1 (133.9 – 196.1)	67.6 (61.2 – 75.5)
Interpersonal violence	1.5 (1.3 – 1.6)	11. 7 (10.4 – 13.2)	0.75 (0.7 – 0.8)	531.8 (408.0 – 661.4)	757.8 (588.6 – 939.2)	294.4 (220.2 – 371.7)
Exposure to forces of nature	0.04 (0.04 – 0.05)	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	0.1 (0.1 – 0.2)
Environmental heat and cold exposure	0.8 (0.7 – 0.9)	4.5 (4.0 – 5.1)	0.36 (0.34 – 0.39)	41.3 (32.7 – 53.1)	280.7 (221.8 – 356.7)	62.9 (44.7 – 88.5)
Conflict and terrorism	0.00 (0.00 – 0.00)	0.12 (0.11 – 0.13)	0.00 (0.00 – 0.00)	0.00 (0.00 – 0.00)	19.4 (15.7 – 23.3)	0.4 (0.3 – 0.5)
Police conflict and executions	0.01 (0.01 – 0.01)	0.07 (0.06 – 0.08)	0.01 (0.01 – 0.01)	0.00 (0.00 – 0.00)	1. 9 (2.4 – 1.4)	0.00 (0.00 – 0.00)

Age-standardized injury mortality rates by European sub-region, 2019

In 2019, in all European countries taken together, 109.7 million people sustained injuries that warranted some type of healthcare and 458,669 people died from injuries. The injury mortality rate per 100,000 individuals varied between European sub-regions. In Eastern Europe, 80 (95% UI: 71.4 to 89.2) individuals per 100,000 died from injuries; twice as high compared to Central Europe (injury deaths 37.8 per 100,000; 95% UI: 33.5 to 42.3) and almost three times as high compared to Western Europe (26.7 injury deaths per 100,000; 95% UI: 25.2 to 27.6). In Eastern Europe self-harm, road injuries and interpersonal violence contributed the most to the injury mortality rate (see Table 1). In Central and Western Europe, the causes of injury that contributed the most to the injury mortality rate were self-harm, road injuries, and falls. The highest variation in mortality rates by cause-of-injury death between European sub-regions was observed for poisonings (21 times higher in Eastern Europe compared to Western Europe), interpersonal violence (16 times higher in Eastern Europe compared to Western Europe) and environmental cold and heat exposure (13 times higher in Eastern Europe compared to Western Europe).

Age-standardized injury DALY rates by European sub-region, 2019

Table 2 shows the DALY rates per 100,000 by cause-of-injury category and by European sub-region. The injury DALY rate per 100,000 was highest in the Eastern European region (5129 DALYs per 100,000; 95%

UI: 4547 to 5864), followed by the Central European region (2940 DALYs per 100,000; 95% UI: 2452 to 3546) and the Western European region (1782 DALYs per 100,000; 95% UI: 1523 to 2115). In Eastern Europe, self-harm (1117 DALYs per 100,000; 95% UI: 980.5 to 1299) and road injuries (1061 DALYs per 100,000; 95% UI: 928 to 1226) contributed most to the injury DALY rate. In Central Europe, falls (706 DALYs per 100,000; 95% UI: 543 to 931) and road injuries (648 DALYs per 100,000; 95% UI: 551 to 754) contributed the most to the injury DALY rate, whereas in Western Europe the major contributors to injury DALY rates were falls (580 DALYs per 100,00; 95% UI: 440 to 768) and self-harm (372 DALYs per 100,000; 95% UI: 360 to 391).

Table 2
DALY rates and per cent change in DALYs 2000–2019 by cause of injury (Level 3) and by European sub-region with 95% uncertainty interval, 2019

	DALY rate (per 100,000)			Per cent of change (%)* (2000–2019)		
Cause of injury	Central Europe	Eastern Europe	Western Europe	Central Europe	Eastern Europe	Western Europe
All causes of injury	2940.1 (2452.3 – 3546.2)	5129.2 (4547.3 – 5864)	1781. 9 (1523.1 – 2115.5)	-28.8	-44.6	-27.0
Road injuries	648.2 (551.5 – 754.0)	1061.3 (928.4 – 1226.4)	314.6 (291.2 – 341.2)	-36.6	-35.0	-55.6
Other transport injuries	60.9 (54.1 – 68.6)	78.6 (68.4 – 93.1)	33.4 (30.8 – 36.4)	-32.3	-8.6	-23.9
Falls	706.3 (542.8 – 931.2)	712.9 (566.8 – 924.1)	580.5 (440.4 – 768.2)	-9.6	-29.1	0.5
Drowning	88.7 (78.7 – 99.9)	273.8 (247.2 – 300.9)	32.1 (30.4 – 33.8)	-51.6	-61.5	-40.3
Fire, heat, and hot substances	86.7 (65.1 – 118.9)	188.9 (164.9 – 220.2)	45.0 (32.4 – 62.3)	-30.0	-55.3	-26.5
Poisonings	43.6 (35.0 – 53.2)	149.9 (133.8 – 165.9)	16.3 (12.7 – 20.6)	-49.0	-56.7	-24.9
Exposure to mechanical forces	357.4 (247.4 – 513.8)	265.5 (201.4 – 355.8)	122.6 (85.6 – 174.7)	-9.5	-32.3	-16.0
Adverse effects of medical treatment	23.1 (18.1 – 26.7)	27.6 (21.5 – 31.4)	25.5 (22.5 – 27.7)	-13.1	-12.4	-10.8
Animal contact	14.8 (10.8 – 20.0)	14.9 (11.9 – 18.9)	4.5 (3.5 – 6.0)	-19.5	-26.9	-16.2
Foreign body	89.5 (77.7 – 101.4)	189.5 (169.4 – 209.4)	52.6 (46.9 – 59.4)	-33.8	-39.2	-22.3
Other unintentional injuries	148.2 (106.0 – 205.5)	184.5 (149.0 – 235.4)	89.0 (60.2 – 130.0)	-37.5	-38.5	-18.4

*The percent of change is the percentage change in DALY rate in the period from 2000 to 2019. A positive percentage of change indicates an increase; a negative percentage of change indicates a decrease.

	DALY rate (per 100,000)			Per cent of change (%)* (2000–2019)		
Self-harm	508.3 (444.0 – 578.1)	1117.3 (980.5 – 1298.8)	372.2 (359.8 – 390.7)	-28.4	-40.3	-24.9
Interpersonal violence	117.5 (103.0 – 134.1)	633.5 (562.0 – 712.8)	72.2 (64.1 – 81.9)	-46.2	-55.0	-28.4
Exposure to forces of nature	2.6 (2.3 – 2.8)	0.3 (0.2 – 0.4)	0.4 (0.3 – 0.5)	39.4	-89.5	-83.6
Environmental heat and cold exposure	31.2 (27.3 – 35.4)	209.0 (185.8 – 234.2)	18.1 (15.7 – 20.9)	-35.5	-59.8	45.9
Conflict and terrorism	12.7 (8.3 – 20.3)	17.9 (13.8 – 24.9)	2.3 (1.5 – 3.7)	-76.0	-90.3	-53.7
Police conflict and executions	0.7 (0.6 – 0.8)	3.7 (3.2 – 4.2)	0.7 (0.6 – 0.7)	-14.1	-20.5	0.1
*The percent of change is the percentage change in DALY rate in the period from 2000 to 2019. A positive percentage of change indicates an increase; a negative percentage of change indicates a decrease.						

Highest variation in injury DALY rates between the European sub-regions was observed for environmental heat and cold exposure (12 times higher in Eastern Europe compared to Western Europe) and interpersonal violence, poisoning and drowning (all 9 times higher in Eastern Europe compared to Western Europe).

Table 2: DALY rates and per cent change in DALYs 2000–2019 by cause of injury (Level 3) and by European sub-region with 95% uncertainty interval, 2019

Age standardized injury DALY rates by country, 2019

Figure 1 shows the age-standardized DALY rate of injury per 100,000 per country. Injury DALY rates were lowest in Italy (1489 DALYs per 100,000; 95% UI: 1272 to 1764), Spain (1568 DALYs per 100,000; 95% UI: 1323 to 1887) and United Kingdom (1575 per 100,000; 95% UI: 1333 to 1898) and highest in Belarus (4264 DALYs per 100,000; 95% UI: 3489 to 5231), Russian Federation (5163 DALYs per 100,000; 95% UI: 4507 to 5954) and Ukraine (5553 DALYs per 100,000; 95% UI: 4784 to 6401).

Figures 2 shows the DALY rates per 100,000 by cause-of-injury category, by sex, and by country for 2019. Across all the European region countries, injury rates were higher in males than females. For males, DALY rates per 100,000 varied from a high of 9024 (95% UI: 7680 to 10582) in Ukraine to a low of 1952 (95% UI: 1689 to 2290) in the Netherlands, whereas in females DALY rates varied from a high of 2587 (95% UI: 2173 to 3097) in the Russian Federation to a low of 866 (95% UI: 713 to 1054) in Italy. In females, the DALY rates are driven by falls, with highest falls DALY rates in Belgium (751 DALYs per 100,000; 95% UI:

558 to 998), Finland (747 DALYs per 100,000; 95% UI: 542 to 1008), and Slovenia (731 DALYs per 100,000; 95% UI: 538 to 978). However, in Ukraine and the Russian Federation, highest DALY rates in females were observed for road injury rather than falls. In males, falls, self-harm and road injuries were the most prominent causes of injury in the countries with lowest injury DALY rates. In Romania, Slovakia, Bulgaria and Albania exposure to mechanical forces becomes a more important cause of injury DALY rates, whereas in countries with the highest injury DALY rates in males (Republic of Moldova, Latvia, Lithuania, Belarus, the Russian Federation and Ukraine) the high DALY rates due to self-harm stand out.

Changes in DALY rates, 2000 – 2019

Between 2000 and 2019 injury DALY rates in Eastern, Central and Western Europe have declined by 45%, 29%, and 27%, respectively (see Table 2 and Figure 3). In Eastern Europe the DALY rates of all cause-of-injury categories declined, with largest declines for conflict and terrorism (-90%), exposure to forces of nature (-90%), and drowning (-62%). In Central Europe the DALY rates of all cause-of-injury categories declined expect for exposure to forces of nature (+39%). The largest decreases in Central European injury DALY rates were observed for conflict and terrorism (-76%), drowning (-52%), and poisonings (-49%). In Western Europe largest declines were observed for exposure to forces of nature (-84%), road injuries (-56%), and conflict and terrorism (-54%), whereas increases were observed for police conflict and executions (+0.1%), falls (+1%), and exposure to environmental heat and cold (+46%).

Inequalities in DALY rates between European countries

Figure 4 shows the ratio of the DALY rate per 100,000 for highest-ranked to lowest-ranked country in each year from 2000 to 2019. For all European countries, the DALY rate ratio was highest in 2005, with the DALY rate in the lowest-ranking country (Russian Federation) 6.0 times higher compared to the highest-ranking country (Malta). After 2005, the DALY rate ratio between the lowest- and highest-ranking country gradually decreased to 3.7 in 2019. Comparison of the injury DALY rates of the lowest- and highest-ranking countries within sub-region from 1990 to 2017 showed that the DALY rate between the lowest- and highest-ranking country in Central Europe, Eastern Europe and Western Europe fluctuated between 1.5 and 1.3, 2.1 and 1.8 and 2.1 and 1.7, respectively.

The DALY rate ratio varied widely by major cause-of-injury and over time. Largest differences in injury DALY rates across countries were observed for interpersonal violence, ranging from 30.5 in 2002 to 12.2 in 2019. For self-harm, the DALY rate ratio declined from 15.3 in 2000 to 8.3 in 2019. For road injuries and falls, the decline in DALY rate ratio were much smaller. For road injury the DALY rate ratio ranged from 6.4 in 2005 to 5.4 in 2019, whereas for falls the DALY rate ratio declined gradually from 3.1 in 2000 to 2.4 in 2019.

Figure 4: Ratio of DALY rate per 100,000 in the highest to lowest ranking country, for all countries in Europe (Europe) and for European sub-regions between 2000 and 2019

Discussion

Main findings

Mortality and DALY rates of injury varied widely by European region, country, sex and cause-of-injury category. Overall, the injury death rate in 2019 in Eastern Europe was twice as high compared to Central Europe and almost three times as high compared to Western Europe. The injury DALY rates showed less pronounced differences between Eastern, Central and Western Europe, although also a distinct east to west gradient was observed. Comparison of injury DALY rates by country showed a fourfold difference between the lowest- and highest-ranking country; however, the difference in injury DALY rates by country was larger for males compared to females. The difference in injury DALY rates between highest- and lowest-ranking country declined from 2005 onwards, indicating declining inequalities in injuries between European countries.

Comparison to other studies – change over time

From 2000 to 2019 we observed large declines in injury DALY across all European sub-regions; however, largest declines were observed for Eastern Europe. This is comparable to findings from the study by Sethi et al. on injury inequalities in Europe [15]. Particularly in the period 2005 to 2013 the difference in declined injury DALY rates between the Eastern, Central and Western Europe is striking, with rapid progress in Eastern Europe, intermediate progress in Central Europe and slow progress in Western Europe. Several factors may have contributed to the slow progress in Western Europe, including ageing of the population and the fact that Western Europe had much lower DALY rates at the beginning of the period, thus their margin for improvement is much more reduced. However, there are striking differences in all-cause injury DALY rates and injury DALY rates by cause-of-injury categories across Western European countries, e.g. falls and road injuries. Therefore, it may be worthwhile to investigate injury patterns and prevention measures that have been taken in Western European countries that showed continuous decreasing injury DALY rates. This may lead to the identification of opportunities to reduce the injury DALY rate in Western Europe even further and that may be transferrable to other European sub-regions.

Furthermore, previous studies reported that the financial crisis that hit Europe in 2008 resulted in higher death rates, including higher suicide rates [16, 17]. However, for none of the three European sub-regions we observed increasing injury death and DALY rates between 2008 and 2011. This finding is broadly in line with earlier results from a systematic analysis on suicide mortality trends among global, national, and regional geographies [18]. The different policy responses and particular characteristics of the societal organizations may help to explain the apparent resilience of the population of countries to the potentially fatal health effect of an economic downturn.

Despite the large decline in DALY rates resulting from conflict and terrorism, we observed over this 20-year study period, that in the European sub-regions of Croatia, Serbia, and Bosnia and Herzegovina, the burden of terrorism remained at its peak. An explanation for this may be that the Bosnian War of the early 1990s had a profound impact on health and disabilities, and that many Balkan inhabitants may therefore still be experiencing the long-term consequences of injury, almost 30-years later [19].

In addition, from 2000 to 2019, Eastern Europe had the highest injury mortality rates attributable to cold or hot temperatures. This may be explained by the fact that, in Eastern Europe the 2003 and 2010 heat-waves led to an increased number of deaths [20, 21]. Climate change is expected to affect populations' health by increasing the mortality burden [22]; national prevention plans are therefore needed to reduce the heat- and/or cold-related impact on the injured.

Comparison to other studies – inequalities in injury

Our findings suggest that health inequalities associated with injuries between European countries decline over time. This is contrasting to the findings of two cross-country studies that reported increasing inequalities in Europe over time [12, 13]. Reasons for these differences in findings may be the different metrics that were used to measure health inequalities, namely mortality ratios versus DALY rate ratios. Second, there are differences in the populations that were studied. Gopfert et al. and Sethi et al. studied age mortality rates among children aged 0 to 14 years old in 53 countries included in the WHO European region, whereas our study included all ages in 42 European countries [12, 13]. Third, there were differences in the period that was studied. Gopfert et al. and Sethi et al. reported differences in injury mortality rates for the years 2000 and 2011 and 2015, respectively to measures differences in health inequalities over time, whereas in our study differences in DALY rate ratios from 2000 to 2019 were reported.[12, 13].

From 2003 to 2005 the observed inequalities in DALY rate ratio increased. Main reason for this was that the DALY rate in the Eastern European region increased in this period. An explanation for this finding may be the impact of dissolution of the former Soviet Union and its social and economic consequences on health and mortality in subsequent years [23]. However, others have argued that causes of the increased mortality rates in Eastern European countries are more intricate and may be the result from a combination of lifestyle habits, economic impoverishment, widening social inequality and the breakdown of political institutions [24, 25]. From 2005 onwards, DALY rates in Eastern Europe have decreased more rapidly compared to Central and Western Europe. A possible contributing factor may be the anti-alcohol policies implemented in Russia in 2005-2006, although other factors, such as economic growth and national initiatives to combat the road safety, childhood injury prevention efforts and violence prevention most probably have played a role as well.[26–28]

Strengths and limitations

A strength of this study is that the death rate estimates in European countries were based on complete cause-of-death registration systems [29]. However, nationally representative injury incidence data, essential input for the YLD calculations, were available for 19 of the 44 included countries, of which many datasets were collected 10 or more years ago. Incidence estimates for every European country and recent years were made by using statistical models that use available data on incidence, prevalence, remission, duration and extra risk of mortality due to the injury from the year and country for which incidence is estimated, as well as from previous years and other countries, but these estimates are inherently less accurate for countries without national representative incidence data [1, 14].

The cause versus nature-of-injury matrices, required for the injury YLD calculations, were based on outpatient, inpatient, and emergency room discharge data from an even smaller number of countries, namely seventeen European countries that are spread across the three European regions (Bulgaria, Cyprus, Czechia, Denmark, Estonia, Hungary, Iceland, Italy, Latvia, North Macedonia, Malta, Netherlands, Norway, Portugal, Slovenia, Spain, and Sweden).

Third, in our study the DALY was used to assess the population health impact of injuries in Europe, describe trends over time and inequalities in injuries across countries. The DALY incorporates mortality and disability, which allows for a more complete assessment of the population health impact. Previous studies that investigated injury inequalities across European countries were based on mortality rate ratios rather than DALY rate ratios.

Fourth, in our study the analytical approach chosen to explore inequalities associated to injuries across countries focuses on the extremes by calculating rate ratios between countries with highest and lowest injury rates.

A limitation of the present study is that the GBD study does not provide DALY rates for sub-groups of the population, by socio-economic status or on a small area deprivation level [1]. As a result, we were not able to investigate health inequalities within countries over time. Therefore, we did not investigate injury inequalities by age groups and sex.

Finally, another limitation of this study is that the DALY estimates were based on prevalence-based data. The epidemiological Disease Modeling – Metaregression (DisMod-MR) software tool is used to stream out prevalence from incidence, and this process assumes a steady state where rates are not changing over time [14]. This steady-state assumption may lead to inaccurate estimates of prevalence of long-term disability if there are large trends in incidence rates or mortality.

Conclusions

Injuries in Europe are still a major public health problem. In 2019 across all European region countries, 109.7 million people sustained injuries that warranted some type of healthcare and 458,669 people died from injuries. However, mortality and DALY rates of injury varied widely by European region, country, sex and cause-of-injury category. Injury death and DALY rates were highest in Eastern Europe and lowest in Western Europe, although differences in injury DALY rates decline rapidly, particularly in the past decade. The injury DALY rate ratio of highest- and lowest-ranking country declined from 2005 onwards, indicating continuous declining inequalities in injuries between European countries.

Abbreviations

DALY: Disability-Adjusted Life Year

GBD: Global Burden of Disease

ICD: International Classification of Diseases

YLD: Years Lived with Disability

YLL: Years of Life Lost

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Data are available in a public, open access repository (ghdx.healthdata.org). Select data are available on reasonable request.

Competing interests

None declared.

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Authors' contributions

JH, SP, MM conceptualized and designed the study. JH and PC curated the data. JH, PC, SP, MM, FA, AG, KMI, EN, CN, AR, AZ analyzed and interpreted the data. JH drafted the initial manuscript. JH, PC, SP, MM, FA, AG, KMI, EN, CHN, AR, AZ, KHA, HA, LA, CLA, TA, ICA, OA, AA, AA, AA, JLAM, LEB, MB, TWB, FBA, MB, DAB, ASB, FC, GC, LC, JSC, RASC, NCM, GD, AD, AKD, DDDS, AFF, SMF, EF, PF, FF, UFP, SG, JCG, IRG, NGMG, MG, NIH, JMH, M.TH, SH, II, MDI, IMI, MJ, JBJ, JJJ, MJ, JHK, GAK, MABK, AK, SK, AK, MK, OPK, CLV, DL, SL, PL, SL, JAL, RL, AMC, EAM, AM, RJM, AFAM, AM, TM, TM, BM, AM, MM, SM, LM, FM, MDN, IN, SN, BO, HO, AO, NO, SSO, APM, SPJ, SP, JP, PP, MP, IR, CRR, SR, DLR, VR, LR, DS, FS, MMSM, BS, AS, RS, SS, IDS, RS, VYS, AAS, CGS, BS, RARCS, PS, RTS, MRTP, FT, SV, TJV, MV, FSV, VV, YW, AY, SY, MSZ, and AZ 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.

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Figures

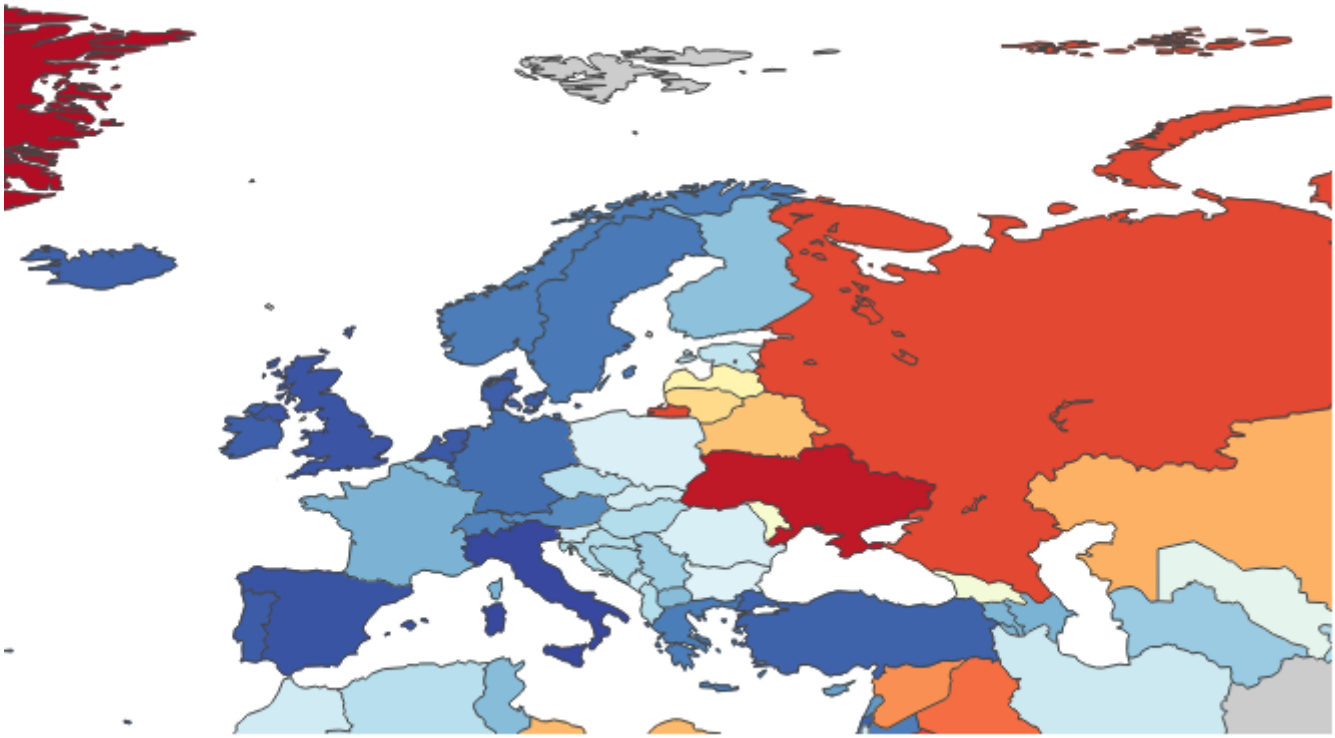

Figure 1

Map figure with age-standardised DALY rate of injury per 100,000 per country, 2019

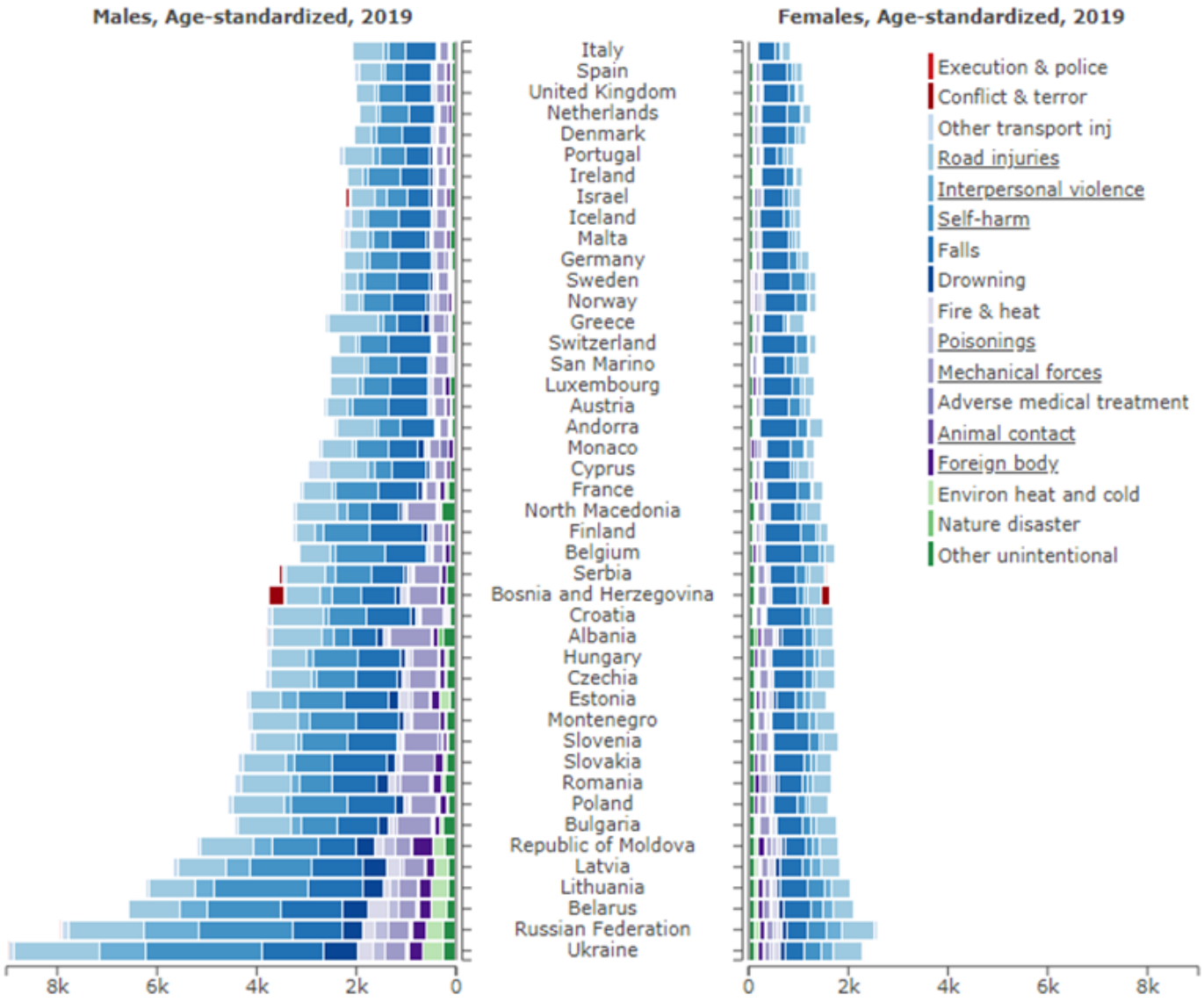

Figure 2

Pyramid figure with DALY rate by sex, country and cause of injury (Level 3), 2019

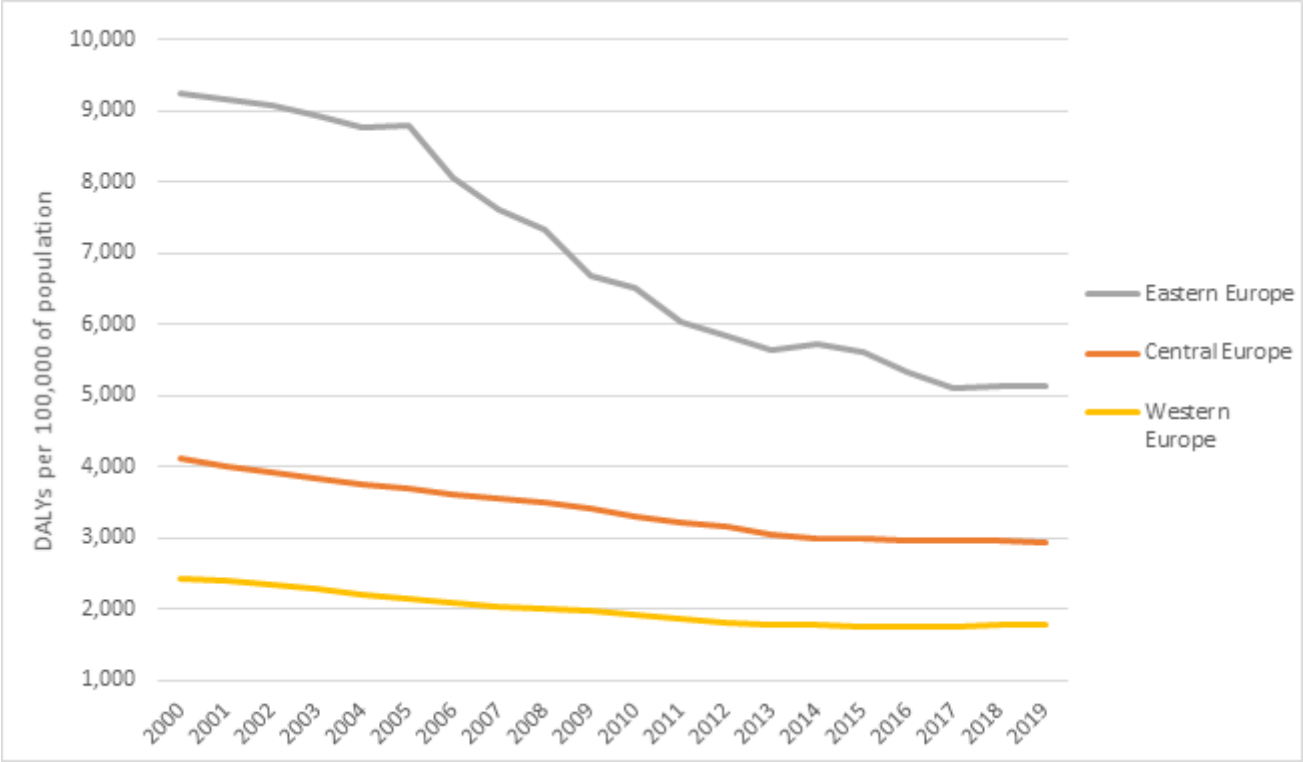

Figure 3

Age-standardized injury DALY rates, by European sub-region, 2000 – 2019

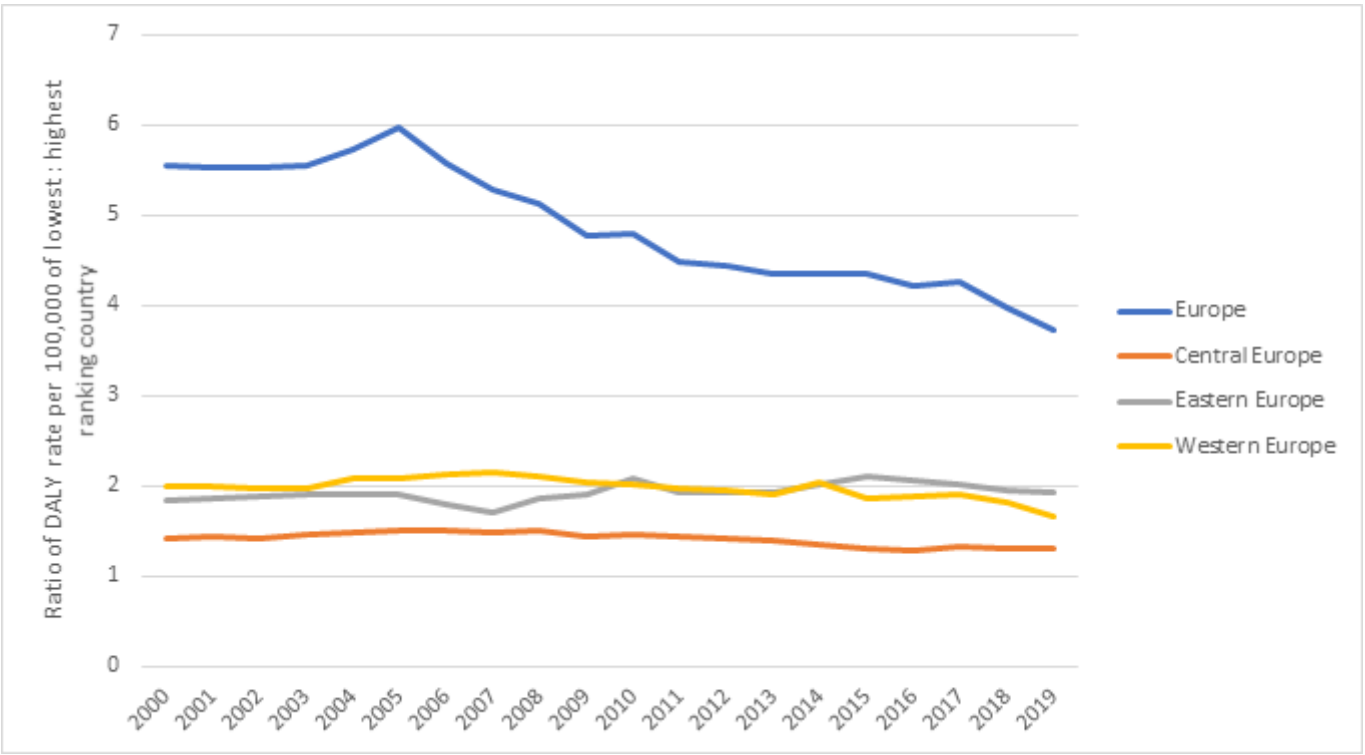

Figure 4

Ratio of DALY rate per 100,000 in the highest to lowest ranking country, for all countries in Europe (Europe) and for European sub-regions between 2000 and 2019