

The Global, Regional, and National Patterns of Change in the Burden of Skull Fractures from 1990 to 2021 and the Forecast for 2036: A Global Burden of Disease Study

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Abstract: *Background:* Skull fractures are a significant public health concern worldwide. The study aimed to measure the incidence, prevalence, and years of life lived with disability (YLDs) for skull fractures from all causes of injury in every country, to describe how these measures have changed and provide crucial information for the development of targeted prevention and treatment strategies. *Methods:* Data from the Global Health Data 2021 were used to measure the global, regional, and national burden of skull fractures by country, region, age, gender, and sociodemographic index (SDI). Age-period-cohort modeling, the AutoRegressive Integrated Moving Average (ARIMA) model, and joinpoint regression analysis were also carried out. *Results:* The global prevalence and YLDs of skull fractures increased from 1990 to 2021, marking a 20% and 18% increase. However, the global prevalence and YLDs rates of skull fractures declined from 1990 to 2021, with an EAPC of -1.37 (95% CI: -1.41 to -1.33) and -1.38 (95% CI: -1.42 to -1.34). The global incidence of skull fractures declined from 1990 to 2021, marking a 3% reduction. Skull fracture incidence rates, prevalence rates, and YLDs rates increased, followed by the rise of the SDI value. In 2021, the high SDI regions reported the highest absolute numbers of incident and YLD cases of skull fractures. The age effect across global and SDI regions demonstrates a downward trend with advancing age, except in the 80+ age groups. There were 5 major causes of skull fractures, including falls, road injuries, exposure to mechanical forces, interpersonal violence, and physical violence by other means. Falls were the most important cause of skull fractures. The ARIMA model predicts a global fall in the age-standardized rates (ASR) of prevalence, incidence, and YLDs from 2021 to 2036. *Conclusion:* Drawing on global epidemiological data, this work investigates trends for skull-fracture-related disease burden. While age-standardized rates (ASR) have fallen, worldwide prevalence and total years lived with disability keep going up. This mismatch between trends implies that one-size-fits-all approaches will not work; local context-adapted interventions are therefore required to tackle the expanding burden of such injuries. Even so, aggregate population burden from skull fractures is forecast to decline in the coming 15-year period.

Keywords: Skull fractures; Epidemiology; Global burden of disease; Prevalence

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1. Introduction

Neurological disorders rank as the top source of disability and the second-largest cause of death around the world. A broad spectrum of illnesses falls within this category of central nervous system (CNS) pathologies: infectious conditions, stroke, primary and secondary CNS malignancies, traumatic brain injuries (TBIs), alongside spinal cord injuries. Substantial disease burden also stems from neurodegenerative pathologies, including Alzheimer's disease and other dementia subtypes, Parkinson's disease, multiple sclerosis, and motor neuron disease. Idiopathic epilepsy, migraine, tension-type headache, plus a collection of rare neurological conditions further add to this public-health toll ^[1]. On a global scale, TBIs — among which skull fractures represent an important subgroup — are responsible for considerable morbidity and mortality ^[2]. According to World Health Organization (WHO) estimates, TBIs stand out as a major driver of death and long-term disability; roughly 69 million individuals sustain TBI each year, and a large proportion of these patients present with concurrent skull fractures ^[3–6].

Skull fractures constitute a major public-health issue across the globe, especially in settings where road traffic crashes, falls, and interpersonal violence occur frequently. Clinical presentations cover a wide severity spectrum, ranging from uncomplicated linear fractures to severe comminuted or depressed skull injuries ^[7–8]. Patients with skull fractures may develop multiple adverse sequelae such as intracranial hemorrhage, cerebrospinal fluid leak, secondary infection and seizure episodes ^[9]. The real-world incidence of skull fractures shows marked geographical heterogeneity. Low- and middle-income countries tend to bear higher incidence rates, partly attributable to insufficient road safety regulation, workplace injury risks and limited healthcare accessibility. One Danish registry reported a cranial fracture incidence of 1.2 per 100 000 following head trauma ^[10]. By contrast, in high-income nations, fall-related skull fractures predominate among older adults, whereas younger groups mostly incur such injuries through motor-vehicle collisions and sports activities. Available medical resources, prompt clinical intervention, and concomitant associated injuries collectively shape patient management and final prognosis. Even so, existing literature still lacks a clear picture regarding the regional and socioeconomic distribution of skull fracture incidence. Shifting focus toward preventive strategies to curb skull fracture occurrence has become a promising direction for mitigating its long-term societal burden.

2. Materials and methods

2.1. Data source

Epidemiological datasets analyzed in the present work were retrieved from the Global Burden of Disease Study 2021 (GBD 2021). This dataset supplies up-to-date burden estimates covering 371 disease and injury conditions for 204 countries and territories grouped into 21 geographical GBD regions, with analytical timeframes ranging from 1990 through to 2021 ^[11]. Comprehensive source metadata can be accessed at <https://ghdx.healthdata.org/gbd2021/sources>.

The research was performed in compliance with the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) ^[12]. Raw datasets alongside processing and modeling code associated with GBD 2021 are publicly accessible via the Global Health Data Exchange (GHDx) platform. Moreover, the STROCSS guideline checklist was supplemented for this investigation ^[13].

2.2. Disease definition

Within the GBD analytical framework, fractures are classified by injury nature instead of underlying etiology. The operational definition for skull fractures adopted by GBD draws upon codes from the International Classification of Diseases and Injuries (ICD) ^[14].

2.3. Socio-demographic index (SDI)

Developed by the Institute for Health Metrics and Evaluation (IHME) in 2015, the socio-demographic index (SDI) functions as a composite metric for evaluating regional and national developmental status, and it characterizes how social advancement correlates with population-level health performance. SDI values correspond to the geometric mean of three normalized indicators (each rescaled between 0 and 1): total fertility rate among women younger than 25 years, mean years of schooling for the population aged 15 years and older, and lag-distributed per-capita income. In GBD 2021, all 204 included countries and territories were stratified into five SDI tiers: low (0–0.2), low-middle (0.2–0.4), middle (0.4–0.6), high-middle (0.6–0.8), and high (0.8–1.0) ^[15].

2.4. Age-standardized prevalence rate (ASPR), age-standardized incidence rate (ASIR) and age-standardized YLDs rate (ASYR)

The ASIR and ASPR denote the number of cases per 100,000 individuals, adjusted for variations in population age. In contrast, the ASYR reflects the number of life years lived with disability per 100,000 people. The study calculated the ASR, including ASIR, ASPR, and ASYR, to assess the global burden of skull fractures using the following formula:

$$ASR = \frac{\sum_{i=1}^A a_i \cdot w_i}{\sum_{i=1}^A w_i} \times 100,000$$

where a_i denotes the age-specific rate in the age subgroup and w_i represents the number of individuals in the same age class of the GBD world age-standard population, which came from the GBD Study 2021 Population Estimates 1950–2021 ^[15–16].

2.5. Estimated annual percentage change (EAPC) and percentage change

The estimated annual percentage change (EAPC) serves as a well-validated statistical metric widely adopted to track temporal shifts in incidence, prevalence, and other health-related rates over a given time frame ^[17–18]. In this work, EAPC was applied to quantify how skull fracture prevalence, incidence, and years lived with disability (YLDs) evolved between 1990 and 2021. EAPC values were derived by fitting a linear regression to the natural logarithm of rates, with calendar year treated as the independent variable. After log-transforming each rate observation, the slope coefficient from this fitted linear model was used to compute final EAPC estimates ^[18–19].

$$y = \alpha + \beta x + \varepsilon$$

$$EAPC = 100 \times (\exp(\beta) - 1)$$

The regression formula is specified as: $y = \alpha + \beta x + \varepsilon$, where x denotes the calendar year, y represents the logtransformed rate (prevalence or incidence), α is the intercept term, β stands for the regression slope, and ε corresponds to random error. Model-generated 95% confidence intervals (CIs) were

obtained for each EAPC estimate. A statistically significant upward trend was identified when the lower bound of the 95% CI exceeded zero; conversely, a significant downward trend occurred if the upper bound of the 95% CI fell below zero. Trends were regarded as nonsignificant whenever zero fell within the 95% CI range. Besides EAPC calculations, simple percentage change was calculated to reflect absolute shifts in case counts for prevalence, incidence, and YLDs across 1990–2021, following the formula: Percentage change = (2021 cases – 1990 cases) / 1990 cases.

2.6. Correlation analysis

This study used correlation analysis to assess linear relationships between variables, with correlation coefficients used to judge the strength and direction of pairwise associations. Using the `cor.test` function in R, the study analyzed the correlation between age-standardized skull fracture rates (ASR) and socio-demographic index (SDI) across 21 GBD regions and 204 countries and territories. Scatter plots with fitted trend lines were constructed to intuitively visualize the correlation results^[19–20].

2.7. Age-period-cohort model

The study adopted an age-period-cohort (APC) model to disaggregate temporal variations in skull fracture burden into three independent effect components: age, period, and cohort. Age effects refer to outcome changes related to individual aging. Period effects reflect broad societal and medical changes, including diagnostic updates and treatment improvements, that influence all age groups concurrently. Cohort effects represent differences in fracture risk across successive birth populations. A sum-to-zero constraint was applied during model fitting to resolve collinearity between the three dimensions. This approach enabled the calculation of net drift and local drift to describe long-term secular trends and periodic trend fluctuations, respectively. All age, period, and cohort data were organized into 5-year intervals for consistent APC analysis^[21–22].

2.8. Joinpoint regression analysis

Characterizing long-term time-series patterns is essential for interpreting skull fracture incidence, prevalence, and YLDs. The study ran joinpoint regression using Joinpoint Regression Program version 4.9.1.0 (National Cancer Institute, Rockville, MD, USA) to detect inflection points and characterize changing epidemiological patterns. Annual percentage change (APC) for each segmented time interval and overall average annual percentage change (AAPC), together with their corresponding 95% CIs, were computed. Rising burden was indicated when APC and AAPC point estimates plus their entire 95% CI lay above zero, whereas declining burden was observed when these values fell entirely below zero. *P*-values greater than 0.05 suggested no statistically meaningful shift in rates within the evaluated time segment^[23–24].

2.9. Forecasting the skull fractures over the next 15 years using the autoregressive integrated moving average (ARIMA) model

Future skull fracture incidence and mortality rates spanning 2022–2036 were predicted with the autoregressive integrated moving average (ARIMA) timeseries model. Modeling procedures were completed in R utilizing the `forecast` and `tseries` packages. ARIMA converts nonstationary raw timeseries data into stationary sequences via differencing operations and is defined by three core parameters: autoregressive order (*p*), differencing order (*d*), and movingaverage order (*q*). Autocorrelation and partial autocorrelation function outputs guide parameter selection for model configuration. Such timeseries forecasting supplies evidence

supporting publichealth planning and targeted intervention deployment ^[25–26].

2.10. Data processing and visualization

All data cleaning, computational procedures and plot generation were performed in R software (version 4.3.1). GBD injury aetiologies are organized into four hierarchical levels; source datasets mainly draw upon hospital admission records, injury surveillance registries, civil registration systems and vital-statistics archives. Fracture causes were classified according to external event types, including road-traffic collisions and falls. Clinical records informed calculations for proportional distributions of different causes and associated injury subtypes. When individuals sustained multiple-site fractures, the most severely disabling injury site was selected guided by disability weights derived from household and web-based population surveys. Multinomial regression ensured that summed proportions for all injury outcomes equaled one. Global skull-fracture burden patterns were stratified by sex and predefined age brackets: < 5, 5–10, 10–15, 15–19, 20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84, 85–89, 90–94, and > 95 years.

Figures were plotted with the “ggplot2” package, and final graphic adjustments were completed in Adobe Illustrator (version CS5). Study design, analytical execution, and result reporting followed the Strengthening the Reporting of Cohort Studies in Surgery (STROCSS) guidelines for observational surgical-related research.

3. Results

3.1. Global level

Globally, skull-fracture incident cases decreased moderately from 5 563.8 thousand (95% UI: 4415.9–7124.1 thousand) in 1990 down to 5424.3 thousand (95% UI: 4212.9–7235.1 thousand) by 2021, corresponding to an overall 3% reduction. Meanwhile, the global age-standardized incidence rate (ASIR) dropped from 98.6 per 100000 persons (95% UI: 78.3–126.8) in 1990 to 70.1 per 100000 persons (95% UI: 54.6–93) in 2021, with an EAPC of –1.15 (95% CI: –1.19 to –1.11).

By contrast, worldwide prevalent skull-fracture cases rose from 2005.3 thousand (95% UI: 1 818.6–2 242.3 thousand) in 1990 to 2399 thousand (95% UI: 2 184.6–2 677.2 thousand) in 2021, representing a 20% increase. Nonetheless, global age-standardized prevalence rates fell from 43 per 100000 (95% UI: 39.3–47.4) in 1990 to 29 per 100000 (95% UI: 26.4–32.5) in 2021; EAPC was –1.37 (95% CI: –1.41 to –1.33).

Total global YLDs attributable to skull fractures increased from 136.7 thousand (95% UI: 90.1–191 thousand) in 1990 to 161.2 thousand (95% UI: 108.1–224.6 thousand) in 2021, equivalent to an 18% rise. The corresponding age-standardized YLD rate declined from 2.9 per 100 000 (95% UI: 1.9–4) to 2 per 100000 (95% UI: 1.3–2.7), with an EAPC of –1.38 (95% CI: –1.42 to –1.34) (**Figure 1**).

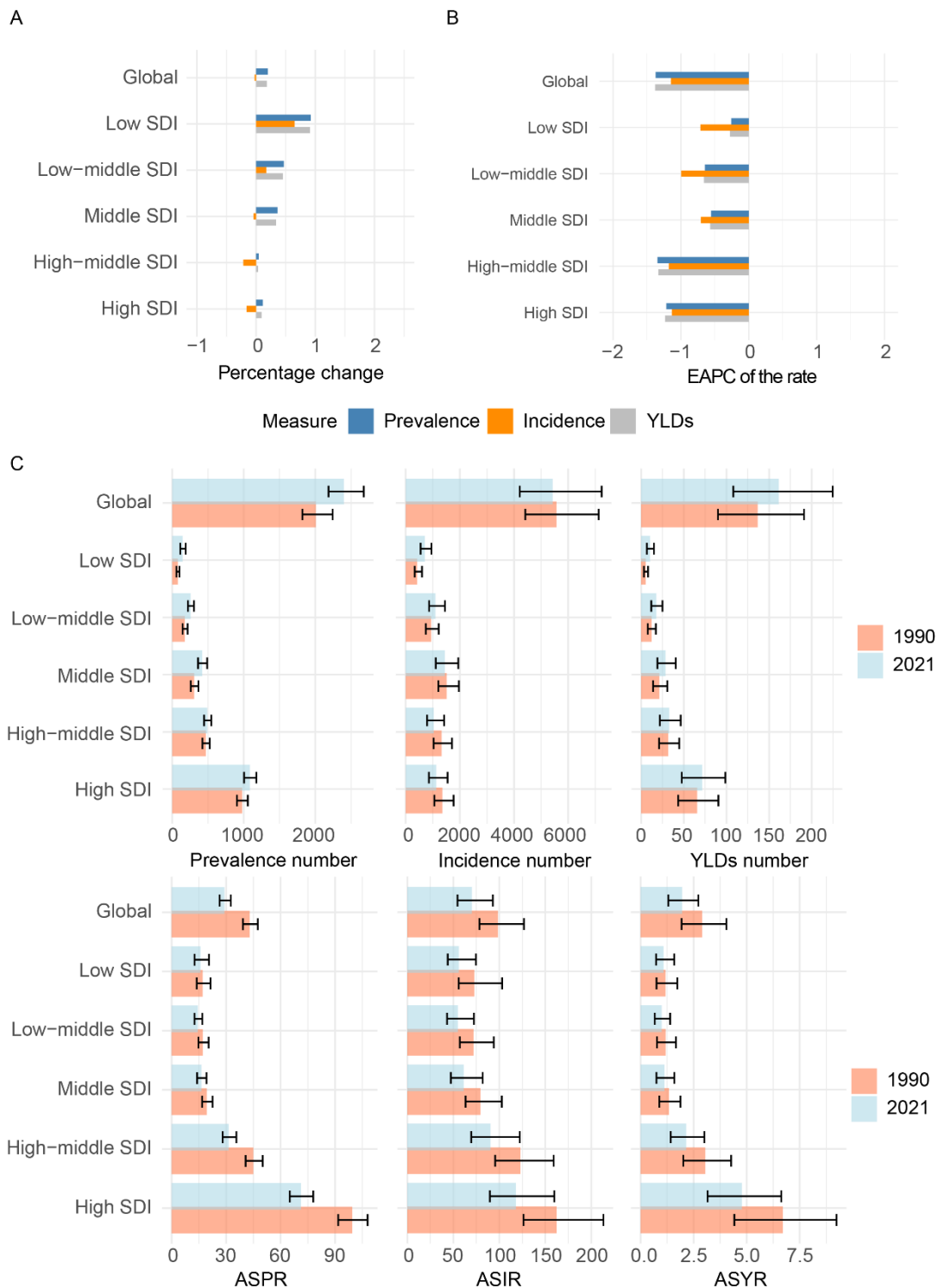


Figure 1. Temporal trend of skull fracture burden in global and 5 SDI regions. (A) Percentage change in cases of prevalent, incident, and YLDs in 1990 and 2021. (B) The EAPC of prevalence, incidence, and YLDs rates from 1990 to 2021. (C) Prevalence, incidence, and YLDs cases and rates in 1990 and 2021. SDI = Socio-demographic index, EAPC=Estimated Annual Percentage Change, YLDs=Years lived with disability

3.2. SDI regional level

In 2021, the high SDI regions reported the highest absolute numbers of incident and YLDs cases of skull fractures, with 1086.7 thousand (95% UI: 1003.1 to 1175.9) and 71.6 thousand (95% UI: 47.7 to 98.7). However, the middle SDI regions reported the highest absolute numbers of prevalent cases of skull fractures, with 1443.8 thousand (95% UI: 1108.7 to 1943.5) (**Figure 1**). The low SDI regions show the largest percentage change (incidence: 65%; prevalence: 92%; YLDs: 92%) from 1990 to 2021. In contrast, the high-middle SDI regions exhibited the smallest percentage change (incidence: -22%; prevalence: 4%, YLDs: 3%) (**Figure 1**). However, from 1990 to 2021, the EAPC in disease prevalence, incidence, and YLD rates exhibited a declining trend in all five SDI regions, and the high-middle SDI regions reported the highest EAPC rates for prevalence, incidence, and YLDs.

3.3. GBD regional level

In 2021, the Australasia regions reported the highest incident, prevalent, and YLDs rates of skull fractures, with 199.7 (140.6–281.3)/105,111 (99.8–123.4)/105, and 7.5 (4.9–10.5)/105, respectively **Figure 2** and **Figure 3**). Over the past 32 years, decreases in prevalence rates and YLDs rates have been observed in more than half of the regions, except the Caribbean and Oceania, while decreases in incident rates have been observed in more than half of the regions, except the Caribbean (**Figure 2** and **Figure 3**).

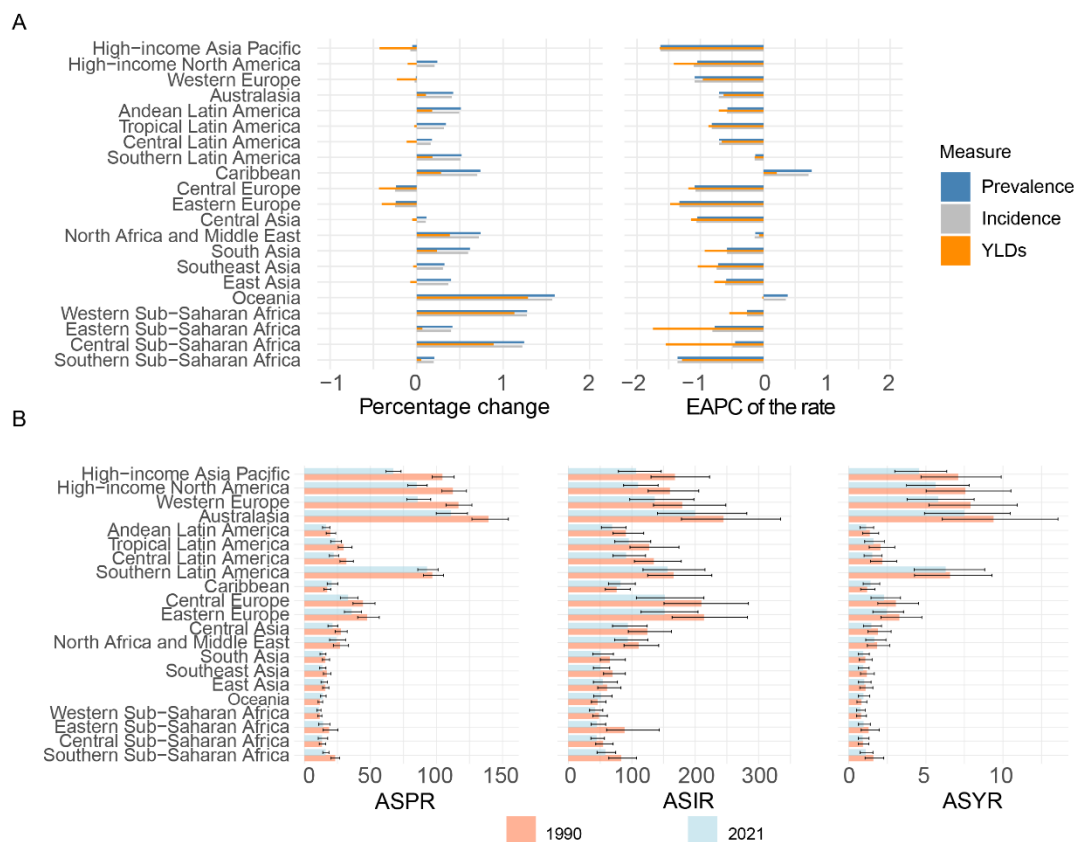


Figure 2. Temporal trend of skull fracture burden in 21 regions. (A) Percentage change in cases of prevalent, incident, and YLDs in 1990 and 2021. (B) The EAPC of prevalence, incidence, and YLDs rates from 1990 to 2021. SDI = Socio-demographic index, EAPC = Estimated Annual Percentage Change, YLDs = Years lived with disability

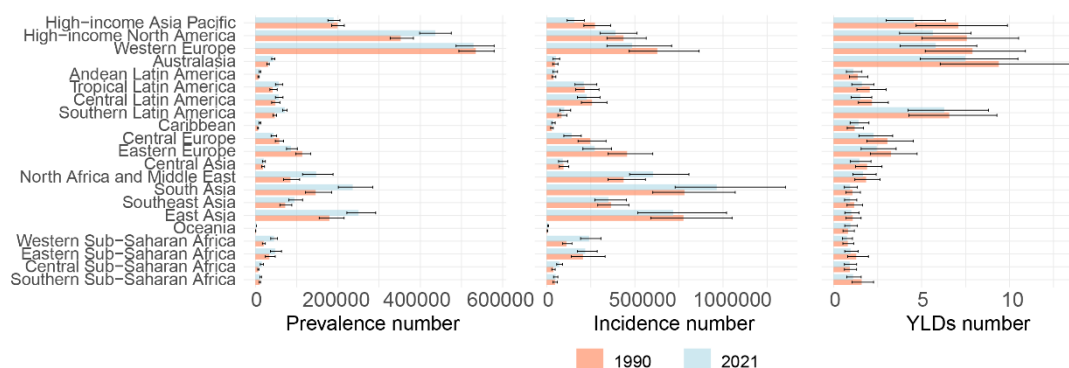
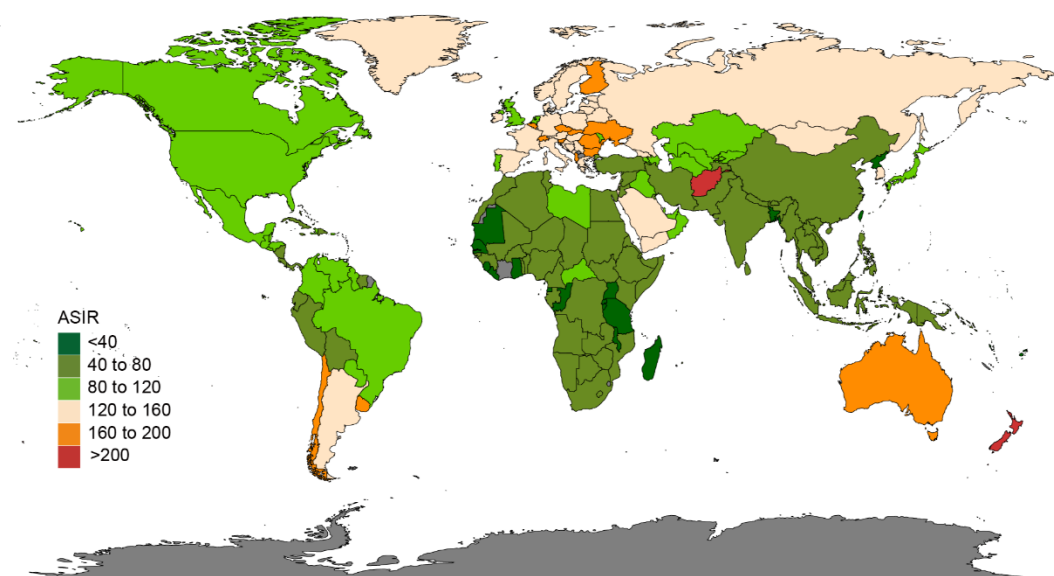


Figure 3. Prevalence, incidence, and YLDs cases across 21 regions in 1990 and 2021

3.4. Countries level

In 2021, the ASIR across the 204 countries was highest in Afghanistan (233.7 per 105, 95% UI: 138 to 425.9 per 105), followed by New Zealand (233 per 105, 95% UI: 165.9 to 324.9 per 105) while lowest in Tonga (29.3 per 105, 95% UI: 22.9 to 38.9 per 105) (**Figure 4**). The three highest countries in EAPC for the incidence rates were the Syrian Arab Republic (incidence: 5.3), Yemen (incidence: 2.21), and Libya (incidence: 2.05). The three lowest countries in EAPC for the incidence rates were Timor-Leste (incidence: -5.83), Burundi (incidence: -4.94), and Liberia (incidence: -4.8).

A



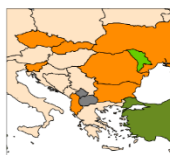
Caribbean and central America



Persian Gulf



Balkan Peninsula



Sotheast Asia



West Africa



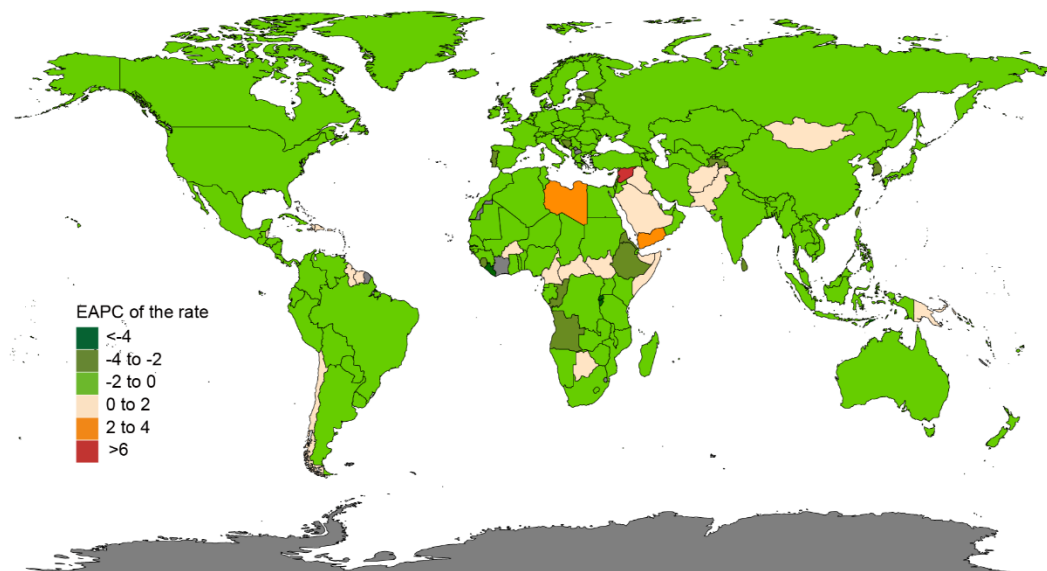
Eastern Mediterranean



Northern Europe



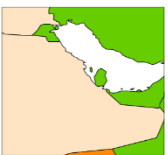
B



Caribbean and central America



Persian Gulf



Balkan Peninsula



Sotheast Asia



West Africa



Eastern Mediterranean



Northern Europe



Figure 4. Temporal trend of skull fracture burden at the country level. (A) ASR in incidence cases across 204 countries in 2021. (B) EAPC in incidence rates across 204 countries from 1990 to 2021. EAPC=Estimated Annual Percentage Change

In 2021, the ASPR and ASYR across the 204 countries was highest in New Zealand (ASPR: 126.9 per 105, 95% UI: 114.9 to 141.8 per 105; ASYR: 8.6 per 105, 95% UI: 5.1 to 11.2 per 105), followed by Andorra (ASPR: 116.3 per 105, 95% UI: 104.8 to 128.1 per 105; ASYR: 8.6 per 105, 95% UI: 5.5 to 12.1 per 105) while lowest in Tonga (ASPR: 7.3 per 105, 95% UI: 6.4 to 8.7 per 105; ASYR: 0.5 per 105, 95% UI: 0.3 to 0.7 per 105) (**Figure 5, Figure 6**). The highest countries in EAPC for the prevalence and YLDs rates were Syrian Arab Republic (prevalence: 5.28, YLDs: 5.23), Haiti (prevalence: 2.27, YLDs: 2.1), Libya (prevalence: 1.94, YLDs: 1.9). The lowest countries in EAPC for the incident rates were Taiwan (Province of China) (prevalence: -2.49, YLDs: -2.47), Portugal (prevalence: -2.48, YLDs: -2.48), Lebanon (prevalence: -2.33, YLDs: -2.36) (**Figure 5 and Figure 6**).

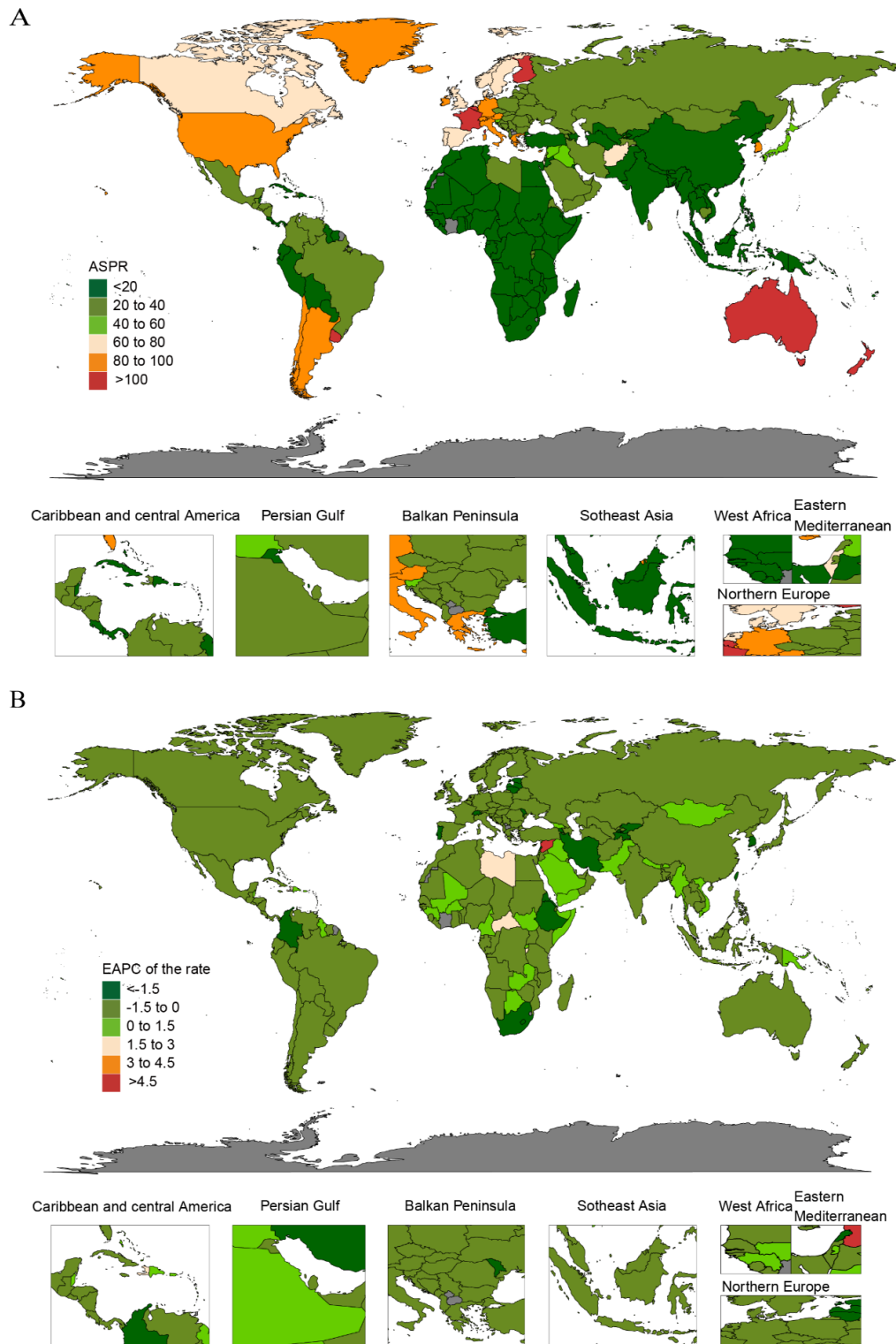


Figure 5. Temporal trend of skull fracture burden at the country level. (A) ASR in prevalent, incidence (Figure 4A), and YLDs (Figure 6A) cases across 204 countries in 2021. (B) EAPC in prevalent, incidence (Figure 4B), and YLDs (Figure 6B) rates across 204 countries from 1990 to 2021. EAPC=Estimated Annual Percentage Change, YLDs=Years lived with disability

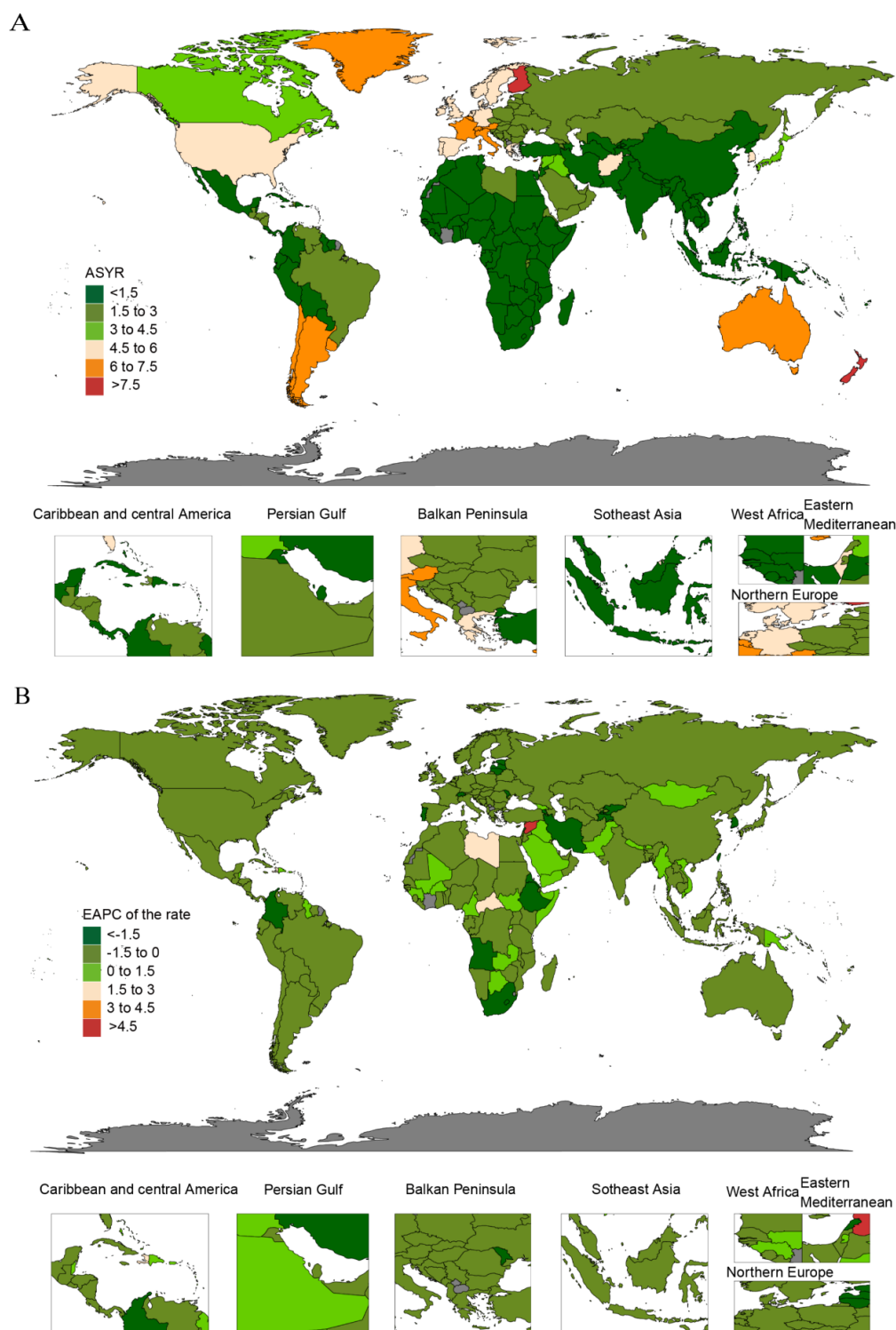


Figure 6. Temporal trend of the burden of skull fractures at the country level. (A) ASR in YLDs cases across 204 countries in 2021. (B) EAPC in YLDs rates across 204 countries from 1990 to 2021. EAPC=Estimated Annual Percentage Change

3.5. Age and sex pattern

Skull fracture incidence differed significantly between sexes and age groups. Males had the highest incidence

at 20–24 years of age, while female incidence peaked in children under five years old. Males showed higher age-standardized incidence rates (ASIR) than females across all age groups younger than 80 years, whereas females had higher ASIR in the population aged over 80 years (**Figure 7**).

Sex differences were also evident in skull fracture prevalence and YLDs. Males reached peak prevalence and YLD rates at 55–59 years, while females peaked later at 65–74 years. Males maintained higher age-standardized prevalence and YLD rates throughout adulthood until age 90, after which females exceeded males in both indicators (**Figure 7**). Male ASIR peaked in early adulthood, and female ASIR was highest in early childhood before declining steadily from 40 to 74 years. Males had higher ASIR than females across all analyzed age strata (**Figure 8**). For both sexes, the 90+ age group had the highest age-standardized prevalence (ASPR) and YLD (ASYR) rates, with males bearing a heavier fracture burden in most age groups.

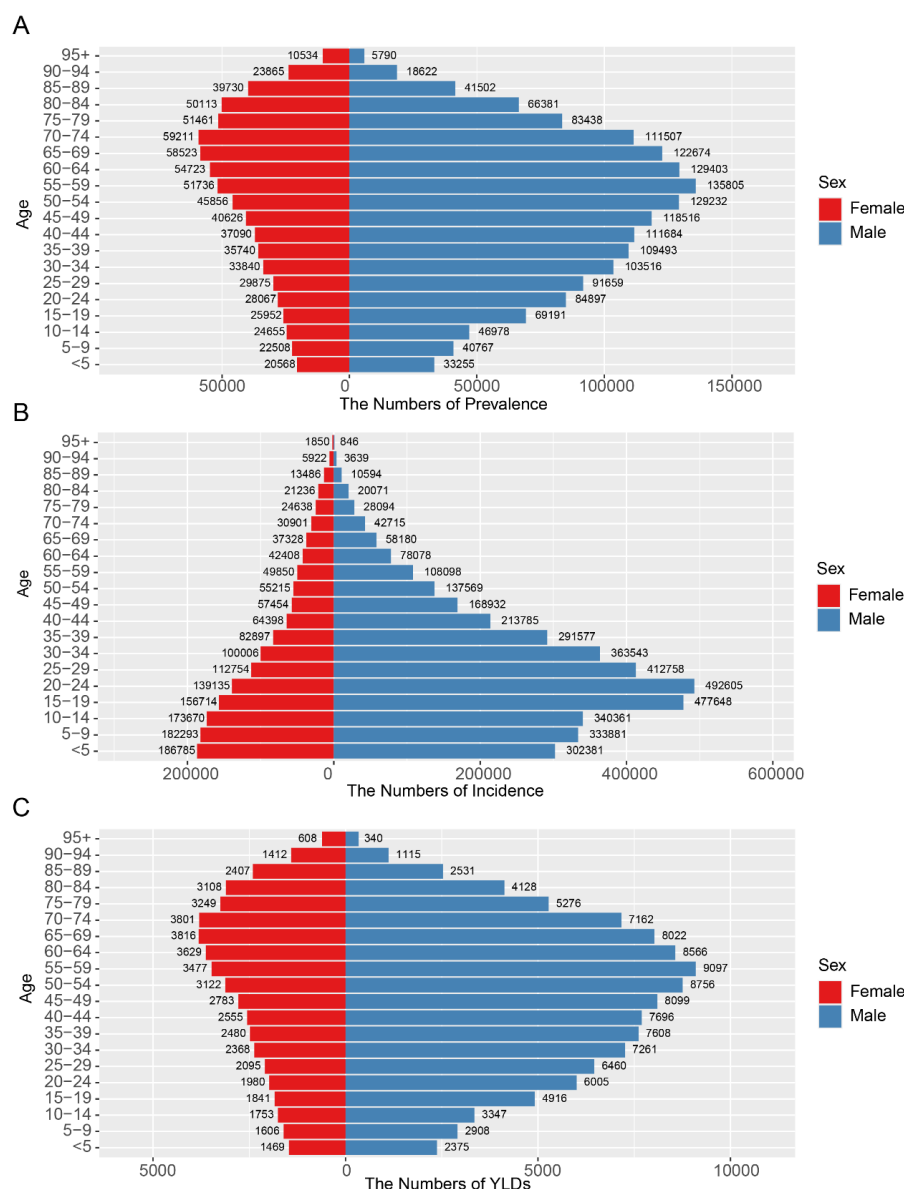


Figure 7. Prevalence, incidence, and YLDs number of skull fracture by age and sex in 2021

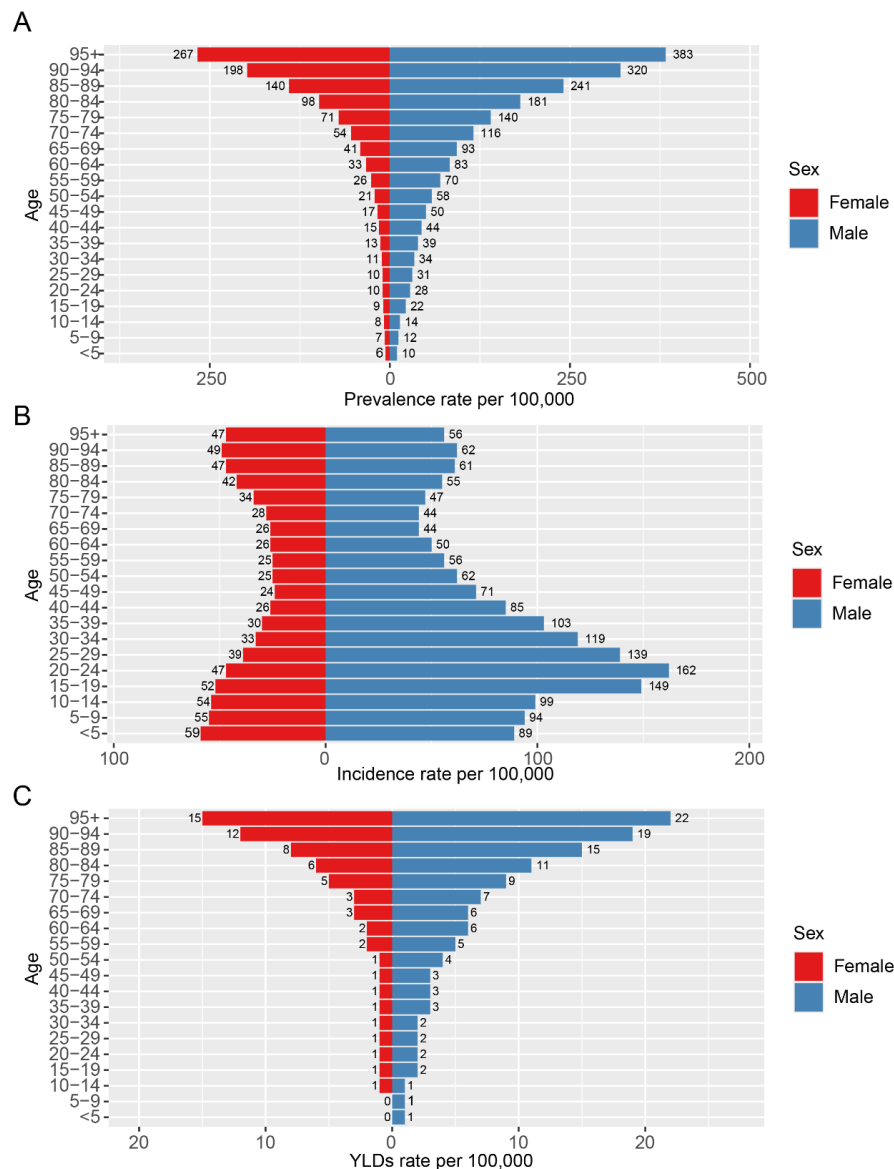


Figure 8. Prevalence, incidence, and YLDs rates of skull fracture by age and sex in 2021

3.6. The association between skull fracture burden and SDI

The study used scatter plots with fitted trend lines to analyze the correlation between skull fracture burden and socio-demographic index (SDI) across 21 GBD regions and 204 countries and territories. The results showed a positive correlation between SDI levels and skull fracture burden, with incidence, prevalence, and YLD rates increasing alongside socioeconomic improvement. Some regions and countries had a higher fracture burden than their SDI levels predicted. Australasia and Southern Latin America showed elevated burden relative to their socioeconomic status. At the national level, New Zealand, Andorra, Belgium, Finland, and Australia all presented higher-than-expected skull fracture burden (**Figures 9–12**).

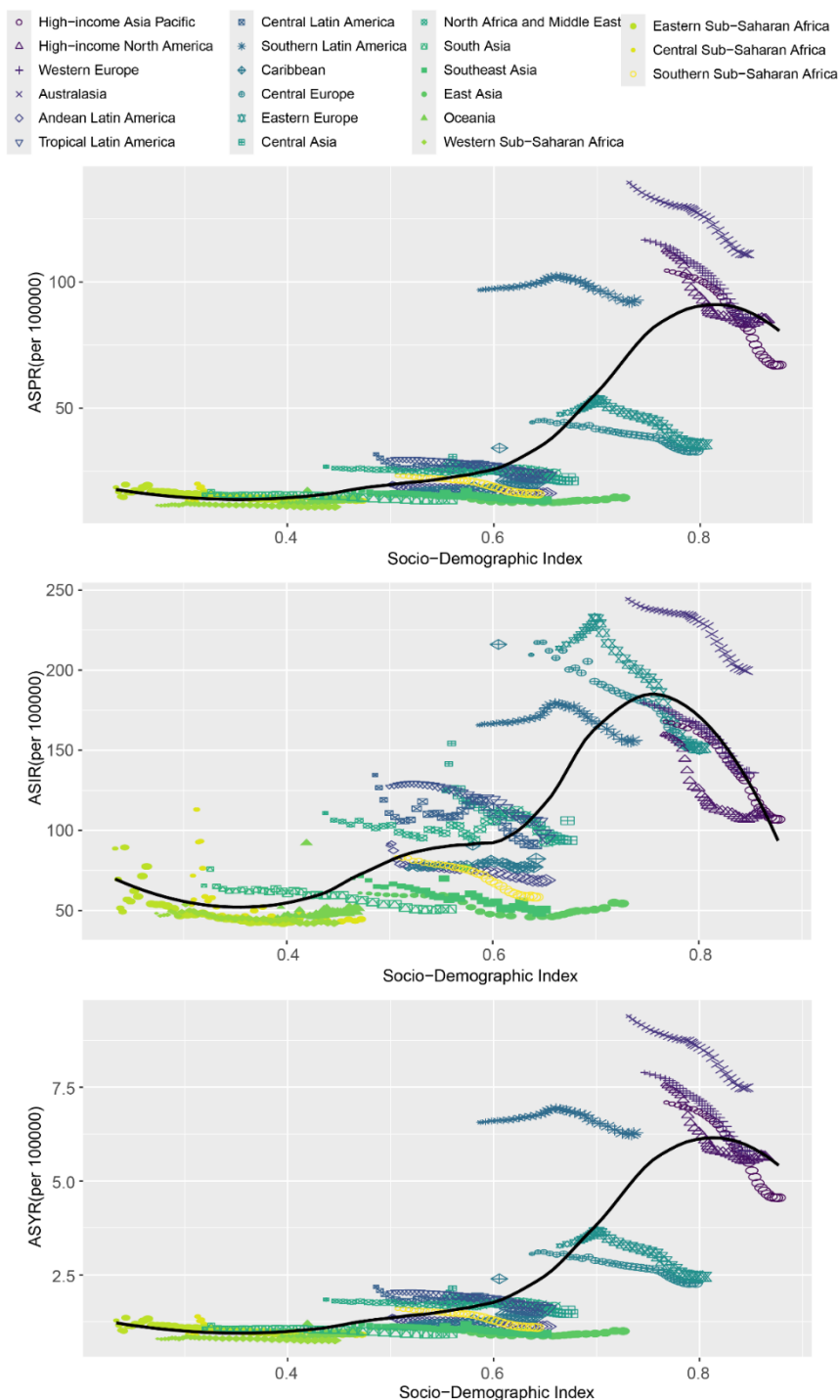


Figure 9. The associations between the SDI and ASR per 100,000 population of skull fractures across 21 GBD regions. (A) Prevalence; (B) Incidence; (C) YLDs SDI=Socio-Demographic Index, GBD=Global Burden of Disease; YLDs=Years lived with disability

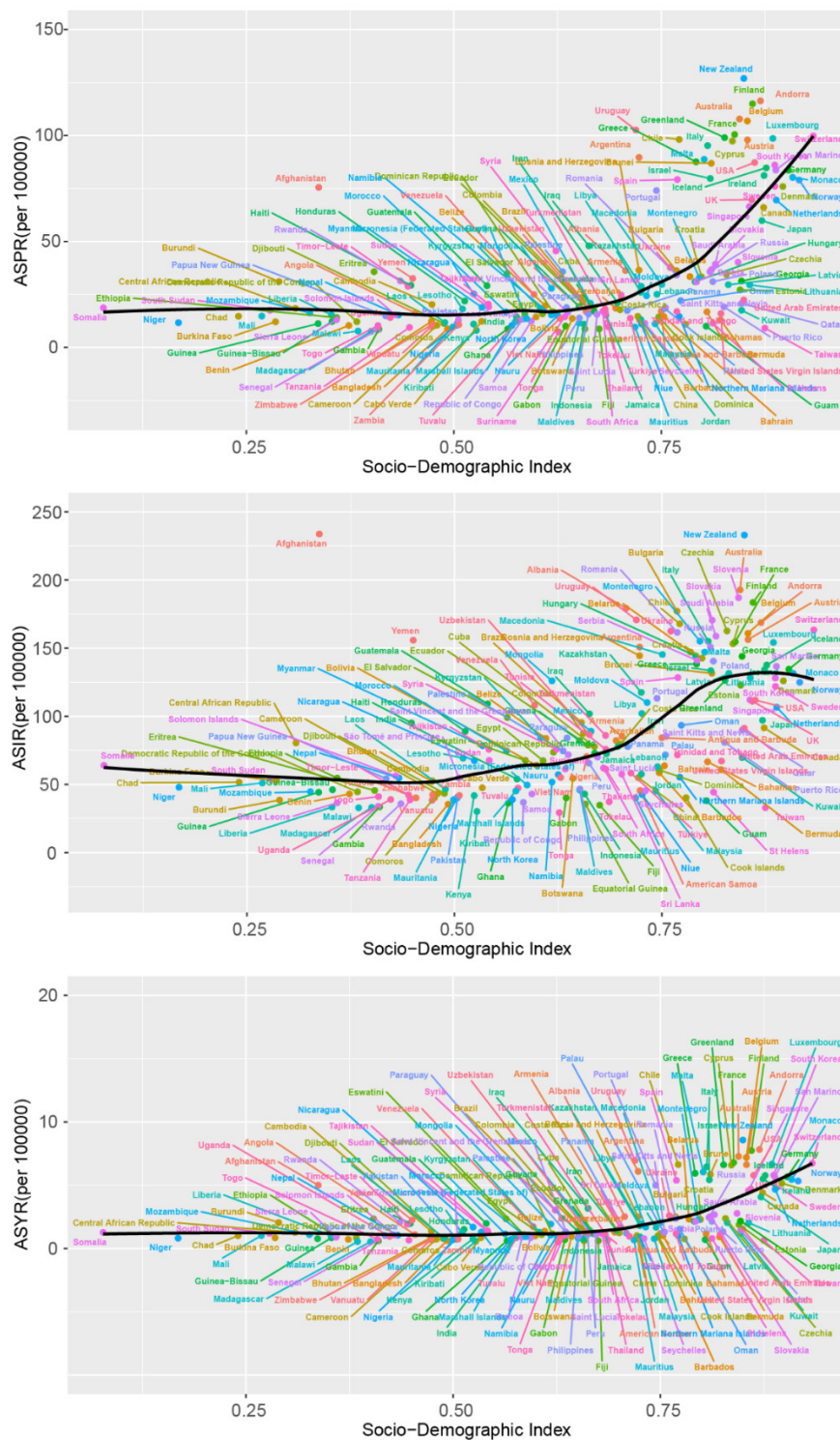


Figure 10. The associations between the SDI and ASR per 100,000 population of skull fractures across 204 GBD countries. SDI=Socio-Demographic Index, GBD=Global Burden of Disease

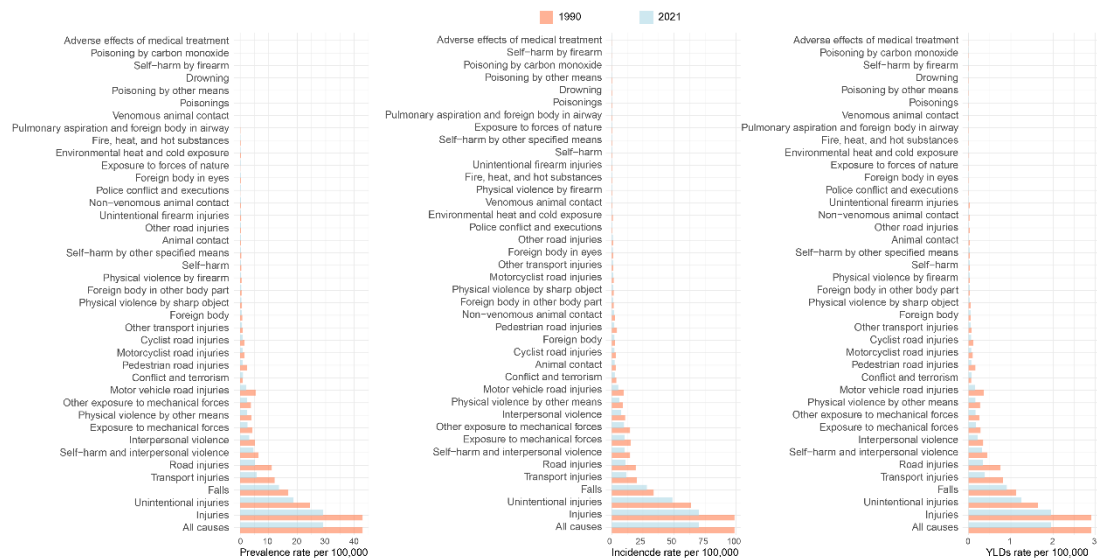


Figure 11. All causes of skull fractures. The cause composition of the number of ASPR (A), ASIR (C), and ASYR (E) of skull fractures between 1990 and 2021

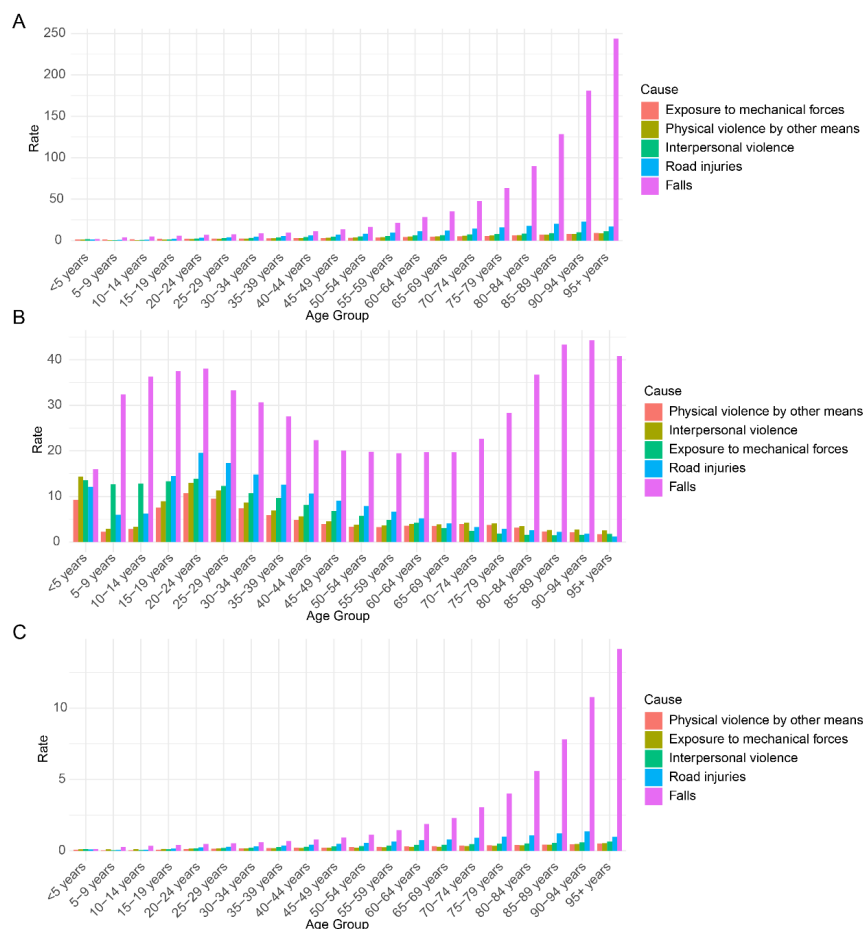


Figure 12. The top five level 3 causes for the ASR of prevalence (A), incidence(B), and YLDs (C) of facial fractures in different age groups in 2021

3.7. Disease burden from different etiologies

The GBD 2021 study identified various causes of skull fractures, detailed in Table S5. Falls were the leading cause, with an ASIR of 28.1 per 100,000 (95% UI: 15.4–49.4), ASPR of 13.6 per 100,000 (95% UI: 11.6–16.5), and ASYR of 13.6 per 100,000 (95% UI: 11.6–16.5) (**Figure 13**) While the overall ASR showed a declining trend, rates associated with conflict, terrorism, and police violence, including executions, increased. Prevalence and YLDs from falls rose significantly with age, and falls were the primary cause of fractures across all age groups. After age 40, fall incidence increased progressively, though a secondary peak was observed between ages 10 and 34 (**Figures 14–17**).

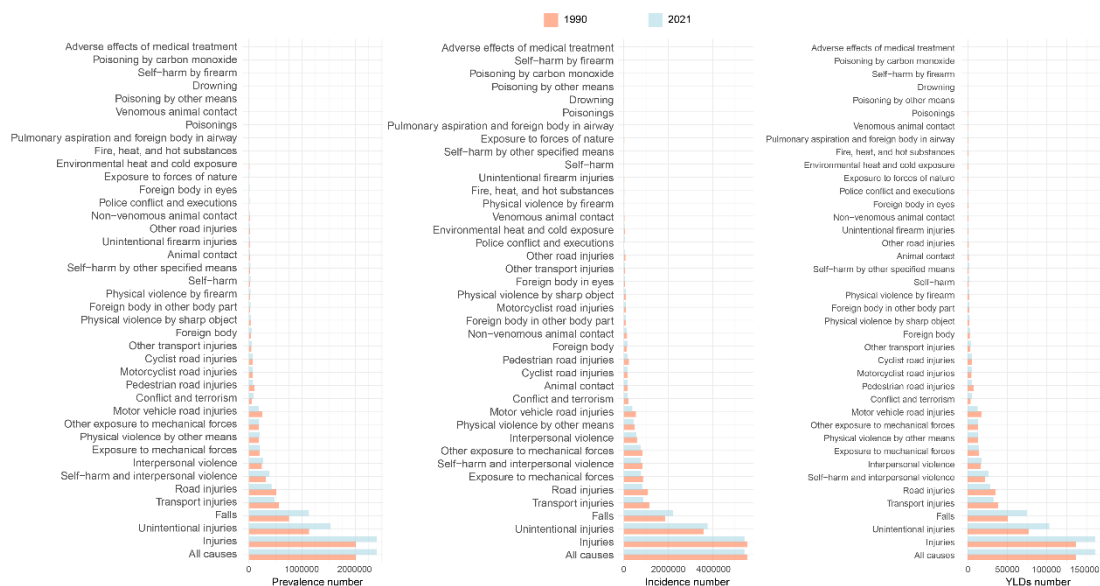


Figure 13. All causes of skull fractures. The composition of causes by prevalence. (A), Incidence (C), and YLDs (E) of skull fractures between 1990 and 2021.

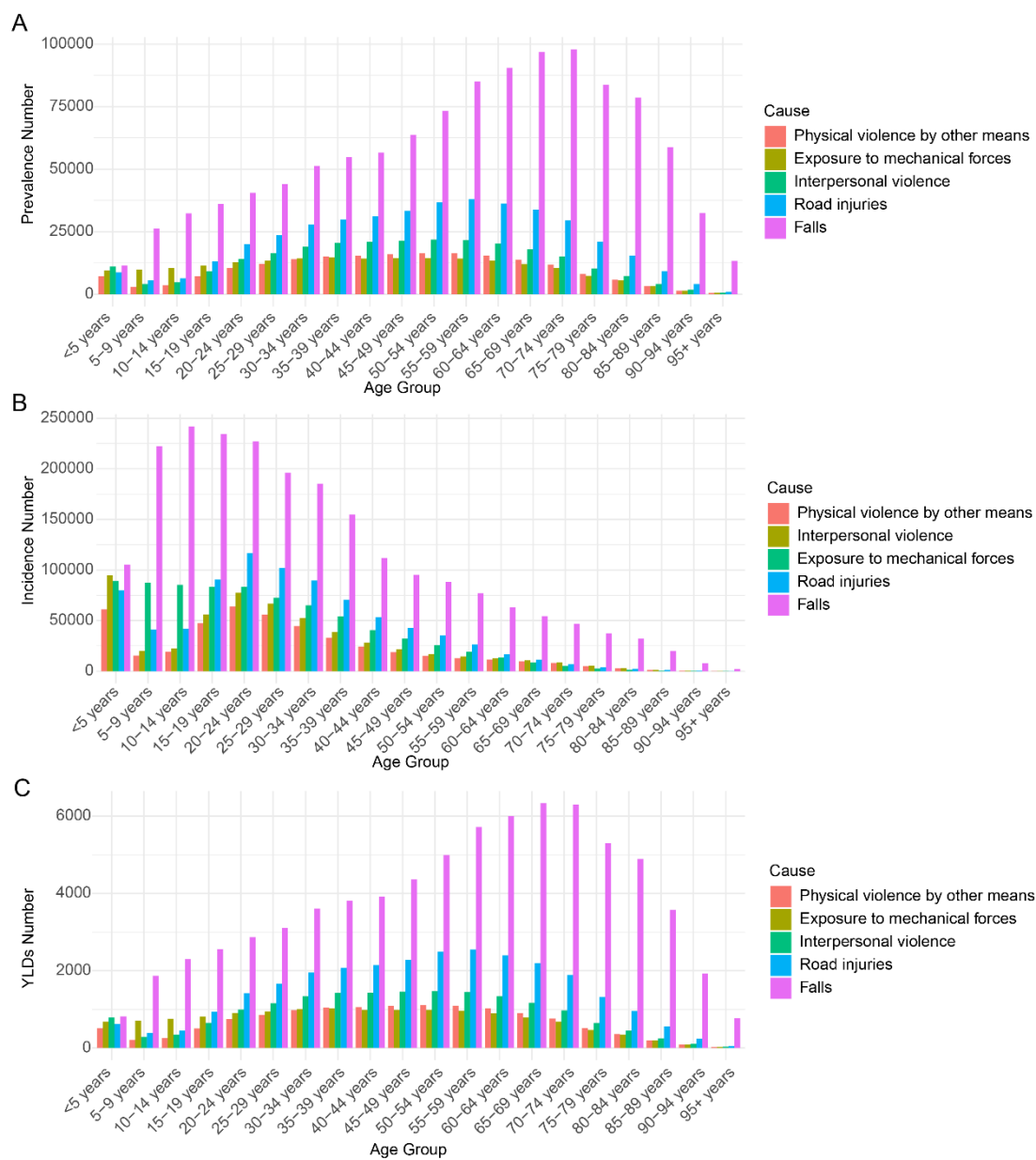


Figure 14. The top five level 3 causes by prevalence. (A), incidence (B), and YLDs (C) of facial fractures in different age groups in 2021

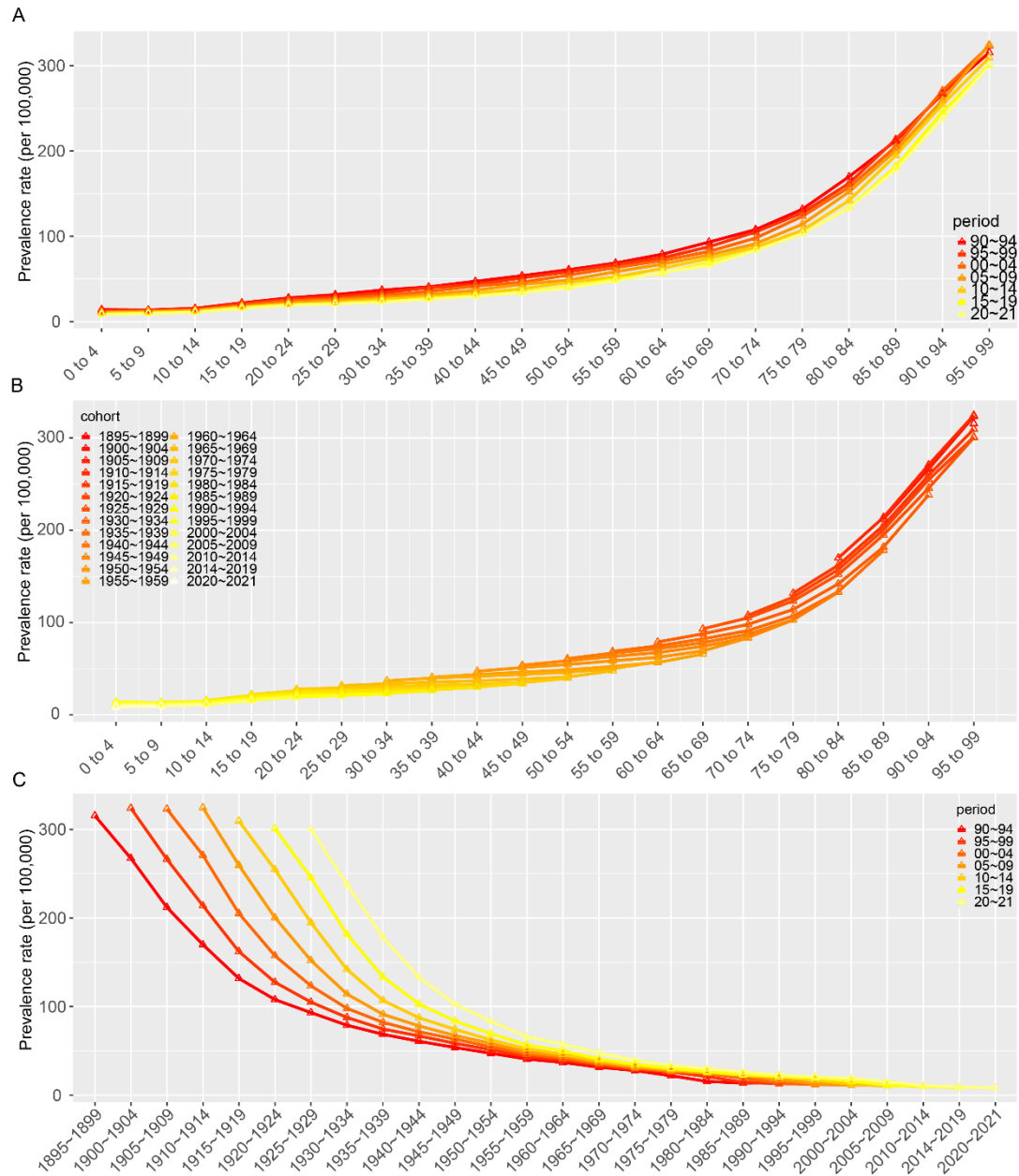


Figure 15. Age-period-cohort effects on skull fracture prevalence globally. (A) Age effects are shown by the fitted longitudinal age curves of prevalence (per 100,000 person-years) adjusted for period deviations. (B) Period effects are shown by the relative risk of prevalence (prevalence rate ratio) and computed as the ratio of age-specific rates from 1990 to 1994 (the referent period) to 2020-2021. (C) Cohort effects are shown by the relative risk of prevalence and computed as the ratio of age-specific rates from the 1895 cohort to the 2020 cohort

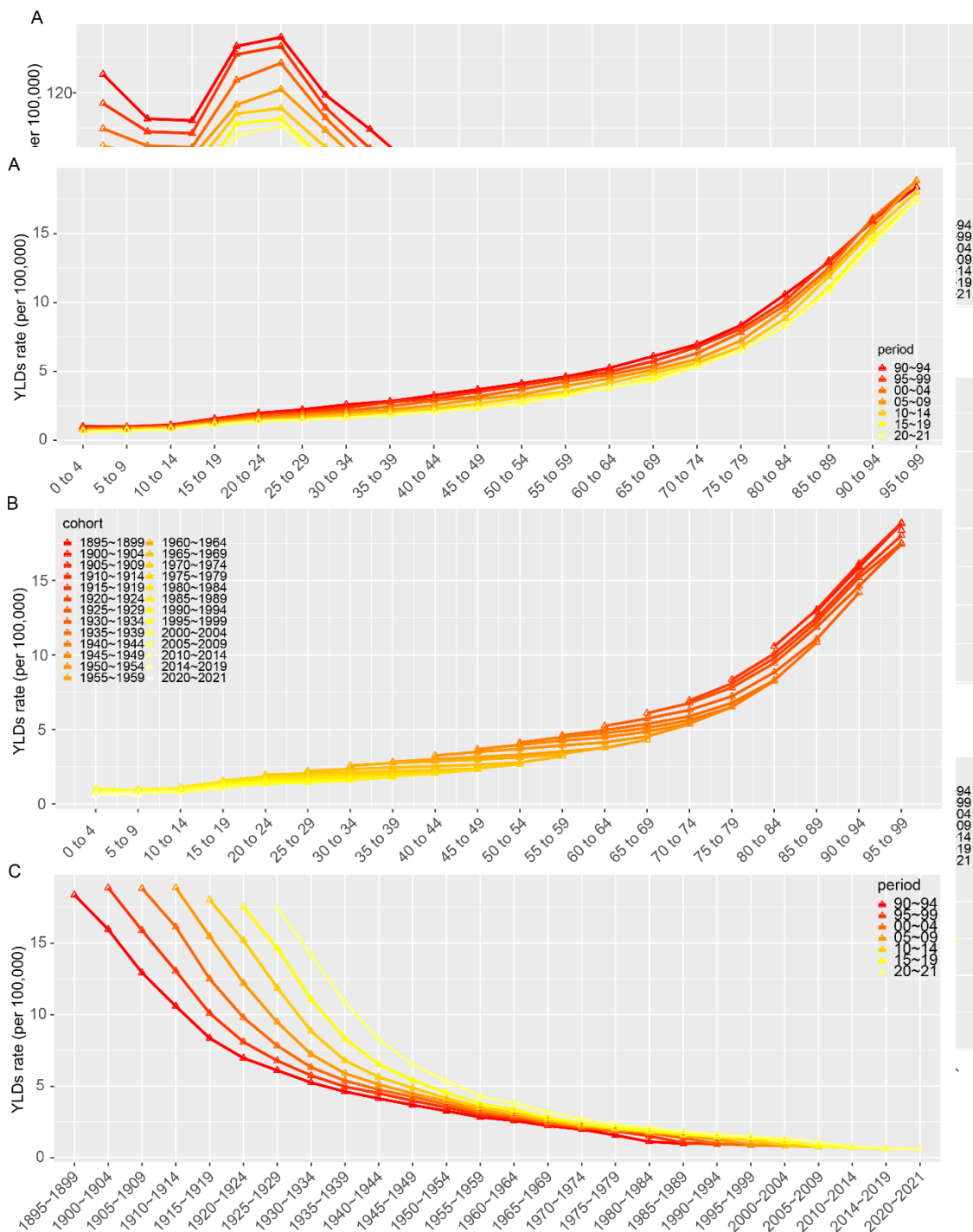


Figure 17. Age-period-cohort effects on skull fractures YLDs globally

3.8. Age-period-cohort analysis

The study also used the APC model to analyze the burden of skull fractures. Globally, the incidence of the age effect peaked at 20–24 years and nadir at 65–69 years. The incidence of skull fractures in the pediatric and teenage group is higher than in the adult and elderly group. As the years progress (period 1990–1994 to period 2020–2021), the incidence of the disease gradually decreases across all age groups except the 80+ age group.

3.9. Joinpoint regression analysis

The study employed the joinpoint regression model to detect shifts in the phase trends of the global burden of skull fractures. **Figure 18** presents the trends in prevalence, incidence, and YLDs related to skull fractures over the past three decades. Overall, the ASIR exhibited a general downward trend globally and across different SDI regions. However, the ASPR and ASYR exhibited a general downward trend globally and across different SDI regions according to the AAPC values, with the exception of Low SDI regions, from 1990 to 2021.

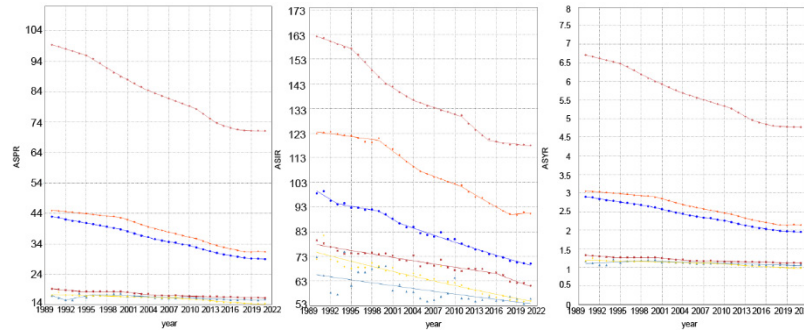


Figure 18. The trends of ASPR, ASIR, and ASYR of skull fractures in global and 5 SDI regions from 1990 to 2021

3.10. Forecasting the next 15 years' trends

The ARIMA model was applied to predict global skull fracture trends over the next 15 years. The forecasting results indicated consistent declines in age-standardized incidence, prevalence, and YLD rates worldwide, with similar downward trends observed across all SDI subgroups (**Figure 19**).

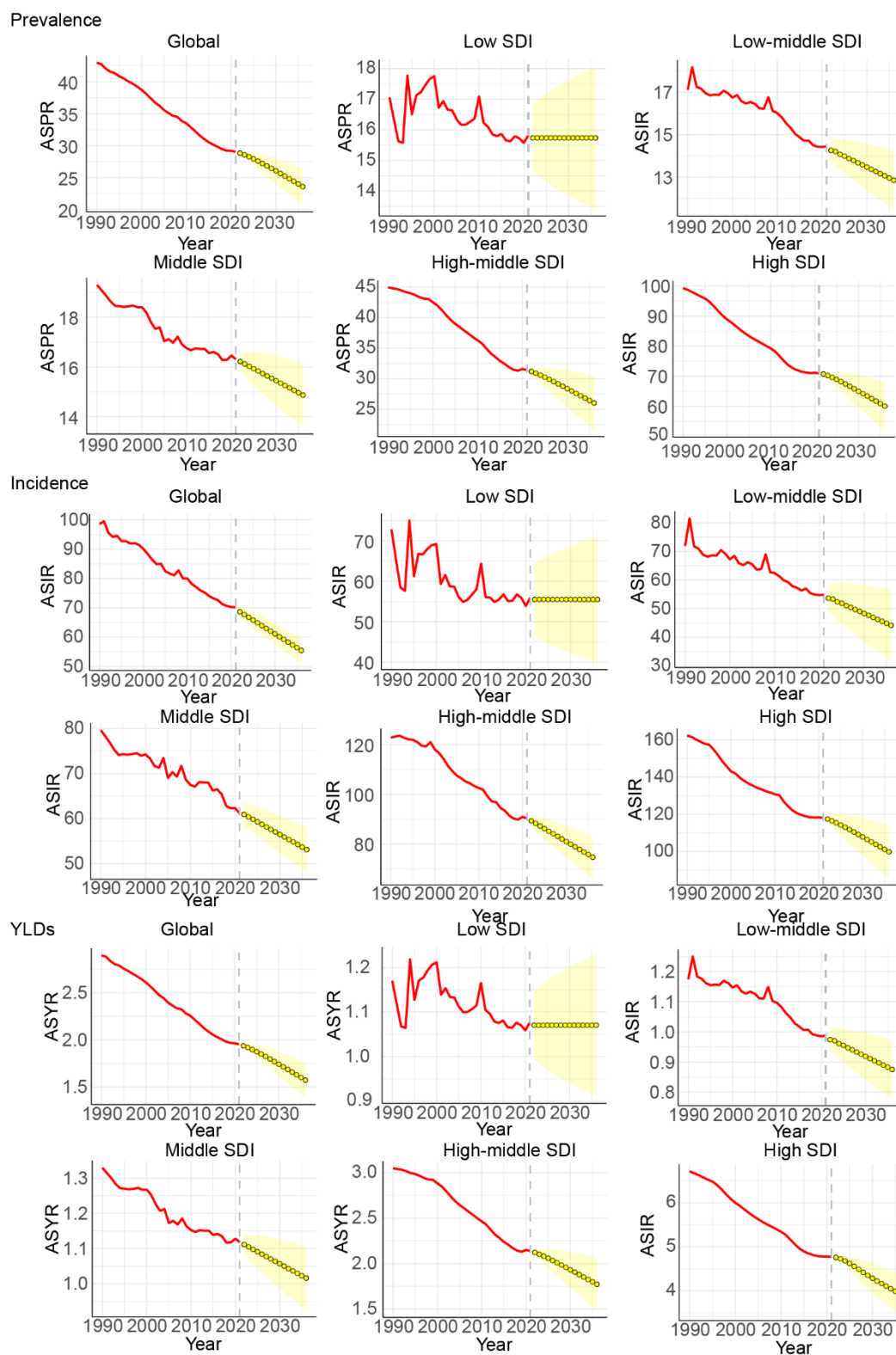


Figure 19. ASPR, ASIR, and ASYR of skull fractures in global and 5 SDI regions from 1990 to 2036

4. Discussion

Few previous studies have comprehensively assessed the global epidemiological features of skull fractures across different ages, sexes, and socioeconomic levels. This study adopted the standard GBD analytical framework to systematically evaluate global, regional, and national skull fracture burden trends from 1990 to 2021. Skull fractures are a major cause of long-term non-fatal disability, affecting populations worldwide and contributing substantially to global traumatic injury burden. Most skull fracture injuries are preventable, suggesting that targeted safety improvements and intervention measures can effectively reduce related public health losses.

Long-term trend analysis showed continuous decreases in global age-standardized incidence, prevalence, and YLD rates of skull fractures over the 31-year study period. This improvement is mainly attributed to fewer falls and traffic injuries, driven by decades of progress in public safety. Updated workplace safety rules have reduced fall-related skull injuries, while improved public traffic safety awareness and widespread head protection use have further lowered fracture risks. Notably, total prevalent cases and YLDs have continued to rise despite falling standardized rates. This opposite trend is mainly caused by global population growth and aging, which expand vulnerable populations and offset the benefits of reduced injury rates.

Correlation analysis confirmed that skull fracture burden positively correlates with regional socioeconomic development. SDI-stratified results revealed declining age-standardized fracture indicators across all five SDI tiers from 1990 to 2021. However, high-SDI regions recorded the largest number of incident cases and YLDs, indicating a heavier actual disease burden in developed regions despite their improving standardized trends.

Several factors explain the high absolute fracture burden in high-SDI regions. Developed regions have longer life expectancy and a larger elderly population. Aging is linked to higher osteoporosis risk and reduced skeletal stability, making older adults more susceptible to skull fractures. Ground-level falls are the leading cause of skull fractures in people aged 75 years and older^[27], so population aging is a key driver of the high burden in high-income areas. In addition, high-SDI regions have mature healthcare systems and complete public health surveillance, ensuring full diagnosis and recording of fracture cases. This avoids underreporting, resulting in higher observed prevalence compared with low-resource regions with inadequate medical monitoring systems.

Large disparities in skull fracture burden existed across countries in 2021. Afghanistan had the highest global ASIR of skull fractures, followed by New Zealand, while Tonga had the lowest. The extremely high burden in Afghanistan stems from long-term armed conflicts and social unrest, which cause massive cranial trauma among civilians and military personnel^[28–29]. Frequent explosions and violent clashes greatly increase fracture incidence. Poor road conditions, lax traffic management, and insufficient medical resources further worsen injury outcomes and delay treatment^[30]. In contrast, Tonga has few traffic accidents and violent incidents, leading to low baseline head injury risk. Nevertheless, its scattered population and limited public health resources restrict systematic epidemiological monitoring, resulting in incomplete case documentation.

Sex-based differences in skull fracture burden were obvious in this study. Overall, males had higher fracture rates than females. Male incidence peaked at 20–24 years, an age group prone to high-risk behaviors including reckless driving, extreme sports, and physical conflicts, which increase cranial trauma risk. Males maintained higher age-standardized prevalence and YLD rates than females before age 90. For females, skull fracture burden was mainly concentrated in early childhood, with stable incidence in older age groups.

Children and adolescents had a higher skull fracture burden than adults and middle-aged populations, mainly due to frequent accidental trauma and risky behaviors. Blunt force trauma, traffic collisions, high falls, and stair accidents are the main causes of pediatric and adolescent skull fractures ^[31]. Consistent with previous studies, the results showed peak fracture burden at 20–24 years and the lowest burden at 65–69 years, with a marked increase in risk among people over 80 years old. The elevated fracture risk in the elderly is closely related to age-related osteoporosis and increased fall susceptibility ^[32].

The findings show that, globally, there were 5 major causes of skull fractures, including falls, road injuries, exposure to mechanical forces, interpersonal violence, and physical violence by other means. Falls represent the primary cause of hospitalized traumatic head injuries in young children, with most pediatric patients admitted for fall-related cranial trauma aged below one year. In such pediatric injury cases, simple linear parietal skull fractures constitute the most prevalent radiological abnormality, while a subset of patients also present concomitant extracranial hemorrhage ^[33]. Compared with standing-level falls, falls from elevated heights — including falls from caregivers’ arms and stair tumbles — substantially increase the risk of sustaining skull fractures in children ^[34]. Beyond accidental trauma, global political turbulence, territorial disputes and external intervention have contributed to rising incidents of armed conflict, terrorism and violent confrontations. Such instabilities have driven a notable surge in traumatic head injuries and skull fractures, predominantly affecting conflict-prone regions including Ukraine, Russia, Sudan, Palestine, Israel, Yemen and the Sahel area.

This study found a gradual decline in global age-standardized skull fracture prevalence, while the total number of affected individuals continues to rise. High-risk groups included children, adolescents, males, and the oldest-old population (over 80 years old). Geographically, Australia, the Caribbean, and conflict-affected regions bore a disproportionately high burden. These findings call for targeted public health interventions to reduce skull fracture prevalence. Effective measures include safety education for young people, improved occupational safety for working-age males, and fall-prevention programs for the elderly, especially in aging high-SDI regions. Reducing regional conflicts is also critical for lowering trauma-related fractures. In addition, the 15-year prediction results suggest that the global skull fracture burden will gradually decrease in the future.

5. Limitations

This study has several limitations. First, all data were obtained from registered medical records and public health databases, which may underestimate the true global skull fracture incidence. Registry data often exclude mild, undiagnosed, and non-hospitalized cases, leading to incomplete population-level case collection. Second, severe underreporting exists in conflict areas. War-related skull injuries are rarely fully recorded during military conflicts, with the Russia–Ukraine conflict as a typical example of overlooked battlefield cases. Third, underdeveloped regions with limited healthcare funding and facilities lack standardized diagnosis and systematic surveillance. Insufficient medical recording capacity in these areas creates gaps between estimated fracture burden and actual epidemiological conditions.

6. Conclusion

In conclusion, while global age-standardized rates of skull fracture incidence, prevalence, and YLDs are

declining, the absolute number of prevalent cases and YLDs continues to rise. Reducing skull fracture incidence requires improved injury prevention strategies, greater public awareness, and robust safety measures. Stabilizing regional conflicts is also essential. Establishing a global skull fracture registry could enhance burden measurement, support research, and improve future epidemiological assessments. The burden of skull fractures is projected to decline over the next 15 years.

Disclosure statement

The authors declare no conflict of interest.

References

- [1] Feigin V, Nichols E, Alam T, et al. Global, Regional, and National Burden of Neurological Disorders, 1990–2016: A Systematic Analysis for the Global Burden of Disease Study 2016. *The Lancet Neurology*, 2019(18): 459–480.
- [2] Ye Z, Li Z, Zhong S, et al., 2024, The Recent Two Decades of Traumatic Brain Injury: A Bibliometric Analysis and Systematic Review. *International Journal of Surgery (London, England)*, 110(6): 3745–3759.
- [3] GBD 2016 Traumatic Brain Injury and Spinal Cord Injury Collaborators, 2019, Global, Regional, and National Burden of Traumatic Brain Injury and Spinal Cord Injury, 1990–2016: A Systematic Analysis for the Global Burden of Disease Study 2016. *The Lancet. Neurology*, 18(1): 56–87.
- [4] Maas AIR, Menon DK, Adelson PD, et al., 2017, Traumatic Brain Injury: Integrated Approaches to Improve Prevention, Clinical Care, and Research. *The Lancet. Neurology*, 16(12): 987–1048.
- [5] Maas AIR, Menon DK, Manley GT, et al., 2022, Traumatic Brain Injury: Progress and Challenges in Prevention, Clinical Care, and Research. *The Lancet. Neurology*, 21(11): 1004–1060.
- [6] Dewan MC, Rattani A, Gupta S, et al., 2018, Estimating the Global Incidence of Traumatic Brain Injury. *Journal of Neurosurgery*, 130(4): 1080–1097.
- [7] Bullock MR, Chesnut R, Ghajar J, et al., 2006, Surgical Management of Depressed Cranial Fractures. *Neurosurgery*, 58(3 Suppl): S56–60.
- [8] Powell EC, Atabaki SM, Wootton-Gorges S, et al., 2015, Isolated Linear Skull Fractures in Children with Blunt Head Trauma. *Pediatrics*, 135(4): e851–857.
- [9] Lin X, Yan Z, Kuang Z, et al., 2022, Fracture R-CNN: An Anchor-efficient Anti-interference Framework for Skull Fracture Detection in CT Images. *Medical Physics*, 49(11): 7179–7192.
- [10] Engberg AW, Teasdale TW. A Population-based Study of Survival and Discharge Status for Survivors after Head Injury. *Acta Neurologica Scandinavica*, 110(5): 281–290.
- [11] GBD 2021 Diseases and Injuries Collaborators, 2024, Global Incidence, Prevalence, Years Lived with Disability (YLDs), Disability-Adjusted Life-Years (DALYs), and Healthy Life Expectancy (HALE) for 371 Diseases and Injuries in 204 Countries and Territories and 811 Subnational Locations, 1990–2021: A Systematic Analysis for the Global Burden of Disease Study 2021. *Lancet*, 403(10440): 2133–2161.
- [12] Stevens GA, Alkema L, Black RE, et al., 2016, Guidelines for Accurate and Transparent Health Estimates Reporting: the GATHER Statement. *Lancet*, 388(10062): e19–e23.
- [13] Mathew G, Agha R, Albrecht J, et al., 2021, STROCSS 2021: Strengthening the Reporting of Cohort, Cross-sectional and Case-Control Studies in Surgery. *International Journal of Surgery*, 2021(96): 106165.
- [14] Zura R, Xiong Z, Einhorn T, et al., 2016, Epidemiology of Fracture Nonunion in 18 Human Bones. *JAMA*

Surgery, 151(11): e162775.

- [15] GBD 2021 Diseases and Injuries Collaborators, 2024, Global Incidence, Prevalence, Years Lived with Disability (YLDs), Disability-Adjusted Life-Years (DALYs), and Healthy Life Expectancy (HALE) for 371 Diseases and Injuries in 204 Countries and Territories and 811 Subnational Locations, 1990–2021: A Systematic Analysis for the Global Burden of Disease Study 2021. *Lancet* (London, England), 403(10440): 2133–2161.
- [16] Liang Y, Dai X, Chen J, et al., 2025, Global Burden and Trends in Pre- and Post-Menopausal Gynecological Cancer from 1990 to 2019, with Projections to 2040: A Cross-Sectional Study. *International Journal of Surgery* (London, England) 111(1): 891–903.
- [17] Zhang H, Huang D, Zhang Y, et al., 2023, Global Burden of Prostate Cancer Attributable to Smoking Among Males in 204 Countries and Territories, 1990–2019. *BMC Cancer*, 23(1): 92.
- [18] Zhang ZX, Xie L, Li Z, 2024, Global, Regional, and National Burdens of Facial Fractures: A Systematic Analysis of the Global Burden of Disease 2019. *BMC Oral Health*, 24(1): 282.
- [19] Yi Y, He X, Wu Y, et al., 2024, Global, Regional, and National Burden of Incidence, Prevalence, and Years Lived with Disability for Facial Fractures from 1990 to 2019: A Systematic Analysis for the Global Burden of Disease Study 2019. *BMC Oral Health*, 24(1): 435.
- [20] Cen J, Wang Q, Cheng L, et al., 2024, Global, Regional, and National Burden and Trends of Migraine Among Women of Childbearing Age from 1990 to 2021: Insights from the Global Burden of Disease Study 2021. *The Journal of Headache and Pain*, 25(1): 96.
- [21] Chen Q, Li T, Ding H, et al., 2024, Age-Period-Cohort Analysis of Epidemiological Trends in Pelvic Fracture in China from 1992 to 2021 and Forecasts for 2046. *Frontiers in Public Health*, 2024(12): 1428068.
- [22] Rosengren BE, Björk J, Cooper C, et al., 2017, Recent Hip Fracture Trends in Sweden and Denmark with Age-Period-Cohort Effects. *Osteoporosis International*, 28(1): 139–149
- [23] Xu B, Radojčić MR, Anderson DB, et al., 2024, Trends in Prevalence of Fractures among Adults in the United States, 1999–2020: A Population-Based Study. *International Journal of Surgery* (London, England), 110(2): 721–732
- [24] Leslie WD, Yan L, Lix LM, et al., 2024, Time Dependency in Early Major Osteoporotic and Hip Re-Fractures in Women and Men Aged 50 Years and Older: A Population-Based Observational Study. *Osteoporosis International*, 33(1): 39–46.
- [25] Wafa HA, Marshall I, Wolfe CDA, et al., 2024, Burden of Intracerebral Haemorrhage in Europe: Forecasting Incidence and Mortality between 2019 and 2050. *The Lancet Regional Health. Europe*, 2024(38): 100842.
- [26] Zhang J, Zhu Y, Wang J, et al., 2024, Global Burden and Epidemiological Prediction of Polycystic Ovary Syndrome from 1990 to 2019: A Systematic Analysis from the Global Burden of Disease Study 2019. *Plos One*, 19(7): e0306991.
- [27] Shibahashi K, Hoda H, Ishida T, et al., 2021, Older Adults with Traumatic Brain Injury in the Most Aged and Most Rapidly Aging Country: An Analysis of the Nationwide Trauma Registry of Japan. *World Neurosurgery*, 2021(150): e570–e576.
- [28] Ashworth E, Baxter D, Gibb I, et al., 2023, Injuries in Underbody Blast Fatalities: Identification of Five Distinct Mechanisms of Head Injury. *Journal of Neurotrauma*. 40(1–2): 141–147.
- [29] Risdall JE, Menon DK, 2011, Traumatic Brain Injury. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 366(1562): 241–250.
- [30] Figueroa C, Linhart C, Fusimalohi L, et al., 2021, Mortality in Tonga over Three Triennia, 2010–2018. *BMC*

Public Health, 21(1): 36.

- [31] Kirvelä A, Snäll J, Suominen A, et al., 2023, Characteristics of Associated Injuries in Children and Teenagers with Craniofacial Fractures. *The Journal of Craniofacial Surgery*, 34(6): 1625–1628.
- [32] Watson WL, Mitchell R, 2011, Conflicting Trends in Fall-Related Injury Hospitalizations Among Older People: Variations by Injury Type. *Osteoporosis International*, 22(10): 2623–2631.
- [33] Settle F, Lawrence D, Kummerow M, 2005, Pre-ambulatory Infants with Head Trauma: A Three-Year Retrospective Study. *Journal of Paediatrics and Child Health*, 41(3): 130–135.
- [34] Burrows P, Trefan L, Houston R, et al., 2015, Head Injury from Falls in Children Younger than 6 Years of Age. *Archives of Disease in Childhood*, 100(11): 1032–1037.

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