Archives of Public Health

RESEARCH

Open Access

Temporal trends in the burden of vertebral fractures caused by falls in China and globally from 1990 to 2021: a systematic analysis of the Global Burden of Disease Study 2021

Zhongjiang Lan[1], Changhao Liu[1], Haojun Wang[1], Yewei Wang[1], Shihu Kan[1], Yanliang Jiao[1] and Yibin Du[1*]

Abstract

Background This study aimed to estimate temporal trends in the burden of vertebral fractures (VFs) caused by falls by gender and age in China and globally from 1990 to 2021.

Methods Data concerning the characteristics of VFs caused by falls in China and worldwide, with a focus on metrics in incidence, prevalence and years lived with disability (YLDs) and their age-standardised rates, were sourced from the Global Burden of Disease (GBD) Study 2021. Joinpoint regression analysis was used to identify periods with significant changes. The average annual percentage change (AAPC) was calculated to reflect the temporal trends from 1990 to 2021. We utilised the age-period-cohort (APC) model to assess the effects of age, period, and cohort on the burden of VFs in China.

Results From 1990 to 2021, the age-standardised incidence rate (ASIR), age-standardised prevalence rate (ASPR) and age-standardised YLD rate (ASYR) of VFs caused by falls exhibited an overall increase in China, whereas a general decline was observed globally. Furthermore, the ASIR, ASPR and ASYR were higher for males than females in China and worldwide. In 2021, across all age groups, the disease burden of VFs was primarily observed among the elderly population, particularly in the older female population, both in China and globally. The impact of age, period, and cohort on the incidence, prevalence, and YLDs exhibited variations in China.

Conclusion The burden of VFs in China remains significant, particularly among older females. Given the considerable size of the elderly population and the ageing of the Chinese population, VFs remain critical public issues. Therefore, continued efforts must be made to address the health consequences of VFs caused by falls.

Keywords Vertebral fractures, Incidence, Prevalence, Years lived with disability, Falls, Osteoporosis, Ageing

*Correspondence:
Yibin Du
lzj000910@163.com; dybtxyx@163.com
[1] Department of Spine Surgery, The Third Affiliated Hospital of Anhui Medical University (The First People's Hospital of Hefei), Hefei, Anhui 230061, China

Text box 1. Contributions to the literature

- This study provides a comprehensive analysis of temporal trends in the burdens of vertebral fractures resulting from falls, offering new insights into Chinese and global health impacts.
- Using data from the latest Global Burden of Disease (GBD) Study 2021 highlights critical epidemiological changes across demographics from 1990 to 2021 in both China and globally.
- The findings contribute to public health by identifying trends that inform targeted strategies for preventing vertebral fractures caused by falls and implementing healthcare policies in China.

Introduction

Vertebral fractures (VFs) are a common treatment challenge in orthopaedics and can be broadly divided into two main types: traumatic and non-traumatic. Traumatic VFs are caused by external forces, such as those experienced in traffic accidents, falls, or sports-related injuries [1, 2]. In contrast, non-traumatic VFs, primarily pathological, are most frequently observed in elderly (>60 years) individuals diagnosed with osteoporosis [3]. In patients with osteoporosis, even minor trauma or daily activities can trigger a fracture. Patients with cancer also face a significant risk of fracture, as bone tumours and bone metastases can cause severe damage to vertebral structures [4]. One study has shown that these fractures are related to a greater risk of death, indicating serious health implications and potential threats to life expectancy [5]. VFs, particularly those associated with osteoporosis, are more prevalent in the elderly female population [6]. The principal reason for this phenomenon is that following menopause, oestrogen levels decrease in females, resulting in a significantly greater risk of osteoporosis and greater vulnerability to VFs than in males [7].

The worldwide distribution of VFs varies significantly [8]. A study including 20,416 participants in China reported that the prevalence of VFs was 10.5% in males and 9.7% in females among individuals aged 40 years and older [9]. A study in Spain of 824 postmenopausal females aged 50 years and older reported that the prevalence of all VFs was 21.4%, and the prevalence of moderate-to-severe fractures was 9.7% [10]. In this study, we drew on data from the Global Burden of Disease (GBD) Study 2021 and compared the burden of VFs caused by falls in China and globally from 1990 to 2021. We aimed to assess the disease burden of VFs caused by falls in China and globally, contributing to formulating effective management and prevention strategies.

Materials and methods

Data sources

The burden metrics of VFs were sourced from the GBD 2021 database (https://vizhub.healthdata.org/gbd-result/). The GBD 2021 provides data on the incidence, prevalence, years lived with disability (YLDs), and other metrics, as well as related 95% uncertainty intervals (UI) due to 71 diseases and injuries, for 88 risk factors, and 204 countries and territories [11, 12]. The GBD Fracture Collaborators have outlined methods for processing, standardising, and modelling the incidence, prevalence, and YLDs associated with VFs [13]. VFs were defined by the International Classification of Disease codes (ICD 9 and ICD 10) in the GBD study. The data on VFs in China are primarily derived from various sources, including Chinese disease surveillance points and disability registration, Chinese injury and risk factor surveillance, emergency department records and hospital records (https://ghdx.healthdata.org/gbd-2021/data-input-sources). Studies utilising Chinese data on different diseases have confirmed the reliability and representativeness of data from the GBD database [14, 15]. Using the GBD 2021 dataset, we adhered to the FAIR data principles (Findable, Accessible, Interoperable, and Reusable). The GBD 2021 dataset is made available by the GHDx, which is a publicly accessible data platform dedicated to providing access to health data. All data are publicly available and can be downloaded by researchers directly through the database interface. Furthermore, The GBD 2021 dataset provides comprehensive metadata, enabling users to gain insight into the provenance of the data, the methodology employed for its collection, and its processing. This facilitates the secondary utilisation of the data. This analysis did not involve animal or human experiments and thus did not require ethical approval.

Incidence, prevalence, YLDs and age-standardised rates

This study analysed the incidence, prevalence, and YLDs related to VFs, along with trends from 1990 to 2021. The term "incidence" describes the number of new cases of vertebral fracture resulting from falls within a defined population over a specified period. The term "prevalence" refers to the proportion of individuals in the population who have experienced VFs caused by falls at any point during the study period. The term "YLDs" denotes the total number of years lived with either short-term or long-term disability resulting from these fractures. To adjust for variations in population age distribution over time, the age-standardised rate of incidence (ASIR), prevalence (ASPR) and YLDs (ASYR) were employed. These standardised rates facilitate more precise comparisons of the disease burden across different populations and time periods, avoiding bias due to differences in the population's age structure.

Age-period-cohort analysis

The age-period-cohort (APC) model was employed to estimate the independent effects of age, time period, and birth cohort on the burden of VFs. To address the collinearity issues often encountered in APC models, the intrinsic estimator (IE) method was applied, leading to more accurate estimates of the effects of age, period, and cohort [16]. In this study, we utilised data from the GBD study to obtain indicators on incidence, prevalence, and YLDs by five-year age groups from 1990 to 2021. To facilitate modelling, individuals under 5 and over 95 years old were combined into a single category, while specific age groups were defined as 0 – 4, 5 – 9, 10 – 14 and so on. Cumulative rates of incidence, prevalence, and YLDs were calculated for each five-year interval (1992 – 1996, 1997 – 2001, 2002 – 2006, etc.). The APC model was fitted using the Epi package (version 2.46) in R software (version 4.4.2), with model selection based on the comparison of residual deviations and AIC values to determine the most appropriate model.

Data adjustment and modelling

The GBD study employs various data sources, including hospital records, emergency department data, insurance claims, surveys, vital registration systems, and others [12]. These data are then modelled to estimate key metrics such as incidence, prevalence, and YLDs. To ensure the accuracy and reliability of the final estimates, several factors were considered during the data collection process. Such factors include inconsistencies in ICD coding over time, variations in injury coding practices across countries, and the potential for duplicate hospital visits. The DisMod-MR 2.1 model, utilised in GBD 2021, provides a robust and consistent method for data analysis through Bayesian inference, to estimate incidence, prevalence, and YLDs associated with VFs. This model effectively adjusts for covariates and draws information from various geographical areas and periods, allowing for a comprehensive analysis.

Selection of falls as the sole cause of VFs

Falls are the most common direct cause of VFs in the elderly, accounting for the majority of fractures [17]. In addition, compared with other causes such as road traffic accidents and sports injuries, VFs caused by falls have a clear aetiological link and are therefore better suited to revealing trends in the burden of disease. The detailed data on falls available in the GBD database support this choice. The following steps are crucial to obtain the desired data: open the GBD 2021 database, select the option "Injuries by nature" in the "GBD Estimate" column, select the option "Fracture of vertebral column" in the "Injury" column, select the option "Falls" in the "Cause" column, select the option "Global and China" in the "Location" column, and select other remaining options and finally download the data. In this way, we can obtain data on VFs resulting from falls and systematically exclude cases of fractures caused by other trauma types.

Statistical analysis

The GBD 2021 study was employed to analyse the incidence, prevalence, and YLD rates associated with VFs, as well as age-standardised rates. Additionally, the crude incidence rate (CIR), crude prevalence rate (CPR), and crude years lived with disability rate (CYR) per 100,000 population for each age group in China and globally were calculated. When we extracted the age data from the GBD 2021 database, ages were divided into consecutive 5-year intervals ranging from < 5 years old to 95 + years old, including children, adults, and the elderly. The Joinpoint regression analysis was utilised to identify periods of significant changes in the incidence, prevalence and YLDs. Meanwhile, we calculated the average annual percentage change (AAPC) and its 95% confidence interval (CI) by using joinpoint software (National Cancer Institute, Rockville, Maryland, USA) [18, 19]. An AAPC greater than 0 indicates an increasing trend, less than 0 indicates a declining trend and equal to 0 indicates a stable trend. Furthermore, to verify the stability of the model estimates, we conducted a sensitivity analysis. We adjusted ASIR, ASPR, and ASYR by setting the upper and lower limits of each metric to ± 20% of the original estimate, respectively. This allowed us to observe changes in AAPC under different scenarios. By comparing the AAPCs before and after adjustment, we could assess the stability of the trends. We performed all data analysis and visualisation via R statistical software version 4.4.2 and Joinpoint software version 5.2.0.

Results

The overall burden of VFs caused by falls in China and globally

In China, the ASIR of VFs resulting from falls increased from 38.57 (95% UI: 24.63–56.88) in 1990 to 52.78 (95% UI: 34.50–77.83) in 2021, with an AAPC of 1.17 (95% CI: 0.80–1.53). Meanwhile, globally, the ASIR decreased from 62.58 (95% UI: 41.29–90.54) in 1990 to 57.93 (95% UI: 38.24–84.47), and its AAPC was − 0.24 (95% CI: − 0.32 to − 0.15) (Table 1). The ASPR in China increased from 19.66 (95% UI: 15.80–24.10) in 1990 to 27.99 (95% UI: 22.75–34.40) in 2021, and its AAPC was 1.28 (95% CI: 0.90–1.65). Concurrently, the global ASPR decreased from 48.73 (95% UI: 41.20–57.74) in 1990 to 44.67 (95% UI: 37.42–53.05), with an AAPC of − 0.27 (95% CI: − 0.33 to − 0.21) (Table 1). The ASYR in China

Table 1 Age-standardised rates of incidence, prevalence and YLDs for VFs in 1990 and 2021, as well as AAPCs during 1990–2021

Region	Indicator	Sex	1990 Rate*(95% UI)	2021 Rate*(95% UI)	AAPC (95% CI)	*P*–Value
China	Incidence	Both	38.57 (24.63–56.88)	52.78 (34.50–77.83)	1.17 (0.80 to 1.53)	<0.001
		Male	44.23 (29.83–63.34)	60.39 (40.67–85.14)	1.17 (0.80 to 1.54)	<0.001
		Female	31.96 (19.37–49.23)	44.06 (27.06–67.16)	1.18 (0.81 to 1.55)	<0.001
	Prevalence	Both	19.66 (15.80–24.10)	27.99 (22.75–34.40)	1.28 (0.90 to 1.65)	<0.001
		Male	20.47 (16.43–25.47)	29.67 (23.87–36.39)	1.28 (0.94 to 1.62)	<0.001
		Female	18.07 (14.52–22.42)	25.53 (20.65–31.19)	1.25 (0.88 to 1.62)	<0.001
	YLDs	Both	2.04 (1.31–2.95)	2.88 (1.85–4.19)	1.25 (0.88 to 1.62)	<0.001
		Male	2.15 (1.39–3.17)	3.09 (2.01–4.52)	1.26 (0.91 to 1.62)	<0.001
		Female	1.85 (1.19–2.70)	2.59 (1.65–3.76)	1.22 (0.86 to 1.57)	<0.001
Global	Incidence	Both	62.58 (41.29–90.54)	57.93 (38.24–84.47)	−0.24 (−0.32 to −0.15)	<0.001
		Male	68.75 (46.96–96.72)	62.59 (42.79–87.37)	−0.29 (−0.38 to −0.19)	<0.001
		Female	54.17 (33.78–82.49)	52.16 (32.88–78.80)	−0.11 (−0.19 to −0.03)	<0.001
	Prevalence	Both	48.73 (41.20–57.74)	44.67 (37.42–53.05)	−0.27 (−0.33 to −0.21)	<0.001
		Male	47.50 (40.51–56.70)	43.95 (37.26–52.11)	−0.24 (−0.31 to −0.17)	<0.001
		Female	47.00 (38.66–56.52)	44.00 (36.20–52.65)	−0.21 (−0.25 to −0.17)	<0.001
	YLDs	Both	4.92 (3.20–6.90)	4.49 (2.92–6.32)	−0.29 (−0.35 to −0.22)	<0.001
		Male	4.87 (3.21–6.92)	4.47 (2.95–6.35)	−0.26 (−0.34 to −0.19)	<0.001
		Female	4.69 (3.00–6.58)	4.38 (2.81–6.18)	−0.22 (−0.26 to −0.18)	<0.001

The Rate* indicates the age-standardised rate per 100,000 population

increased from 1990 to 2021, with an AAPC of 1.25 (95% CI: 0.88 to 1.62). Meanwhile, globally, it decreased from 1990 to 2021, and its AAPC was − 0.29 (95% CI: − 0.35 to − 0.22) (Table 1).

Joinpoint regression analysis of the ASIR, ASPR and ASYR of VFs caused by falls in China and globally

Figures 1 and 2 present the results of the joinpoint regression analysis of the ASIR, ASPR, and ASYR for VFs resulting from falls in China and globally from 1990 to 2021 by gender. These trends highlight the burden of VFs exhibiting higher age-standardised rates in males compared to females, this gender disparity is evident in the incidence, prevalence and YLDs. The joinpoint regression analysis revealed significant shifts in the ASIR in China in 2001, 2005 and 2010, whereas notable changes in the global ASIR were noted in 1995, 2000, 2005, 2010, 2014 and 2018 (Figs. 1 and 2). The increasing periods in the ASIR in China were observed during 1990 – 2001, followed by 2005 – 2021, whereas the decreasing period was in 2001 – 2005 (Fig. 1). However, the decreasing periods in the global ASIR were in 1990 – 1995 and 2000 – 2018, whereas the increasing periods were observed during 1995 – 2000 and 2018 – 2021 (Fig. 2). Additionally, significant shifts in the ASPR of VFs in China were observed in 1995, 2000, 2005 and 2010, whereas substantial changes in the global ASPR were noted in 1994, 2000, 2005, 2010, 2014 and 2018 (Figs. 1 and 2). The increasing periods in the ASPR in China were observed during 1995 – 2000, followed by 2005 – 2021, whereas the decreasing periods were in 1990 – 1995 and 2000 – 2005 (Fig. 1). However, the decreasing periods in the ASPR globally were in 1990 – 1994 and 2000 – 2018, whereas the increasing periods were observed during 1994 – 2000 and 2018 – 2021 (Fig. 2). Furthermore, the significant changes and trends of the ASYR in China and globally were similar to those observed in the ASPR (Figs. 1 and 2).

A sensitivity analysis of the ASIR, ASPR and ASYR in China and globally

We adjusted ASIR, ASPR and ASYR in China and globally by setting each indicator's upper and lower limits to ± 20% of the original estimate, respectively. The AAPC was then recalculated based on the adjusted parameter values. The results showed that even when the upper and lower limits of ASIR, ASPR, and ASYR fluctuate up and down by 20%, the range of variation in AAPC remains minimal and the trend remains stable (Table 2).

The burden of VFs caused by falls across different age groups in China and worldwide in 1990 and 2021

Figure 3 presents a comparative analysis of the incidence, prevalence, and YLDs of VFs caused by falls across different age groups in China and globally for 1990 and

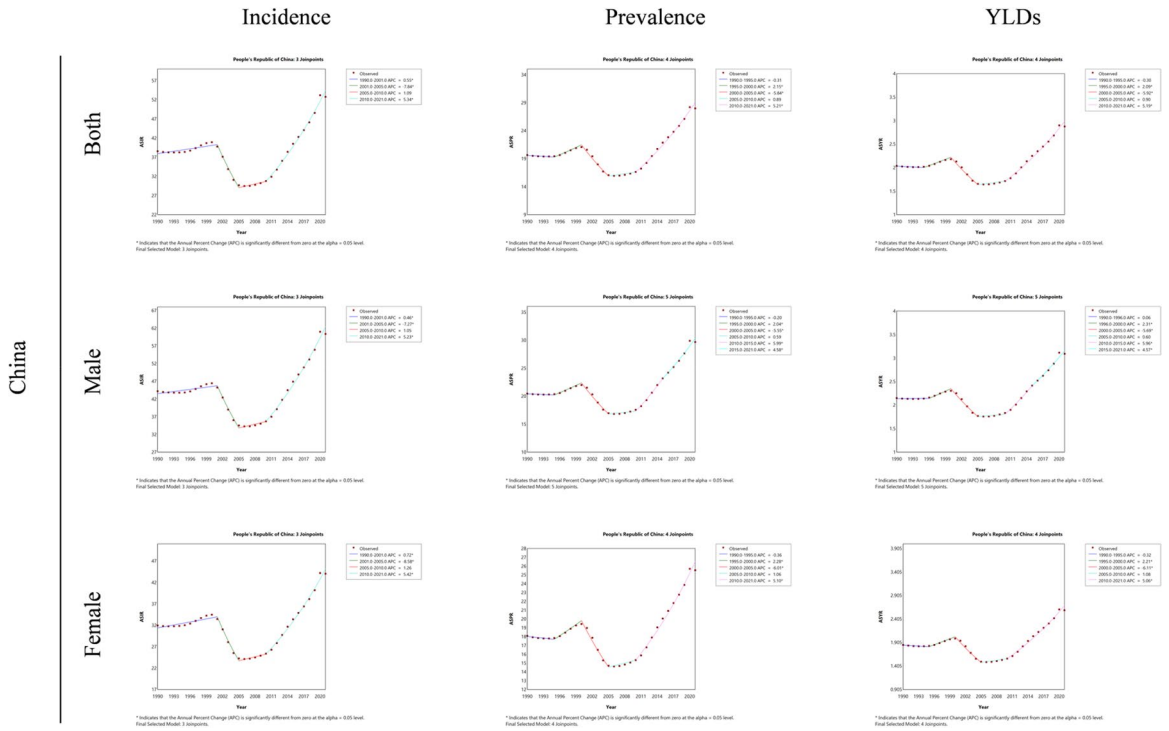

Fig. 1 Joinpoint regression analysis of the ASIR, ASPR, and ASYR for VFs caused by falls for males, females, and both sexes in China during 1990–2021. *$p < 0.05$

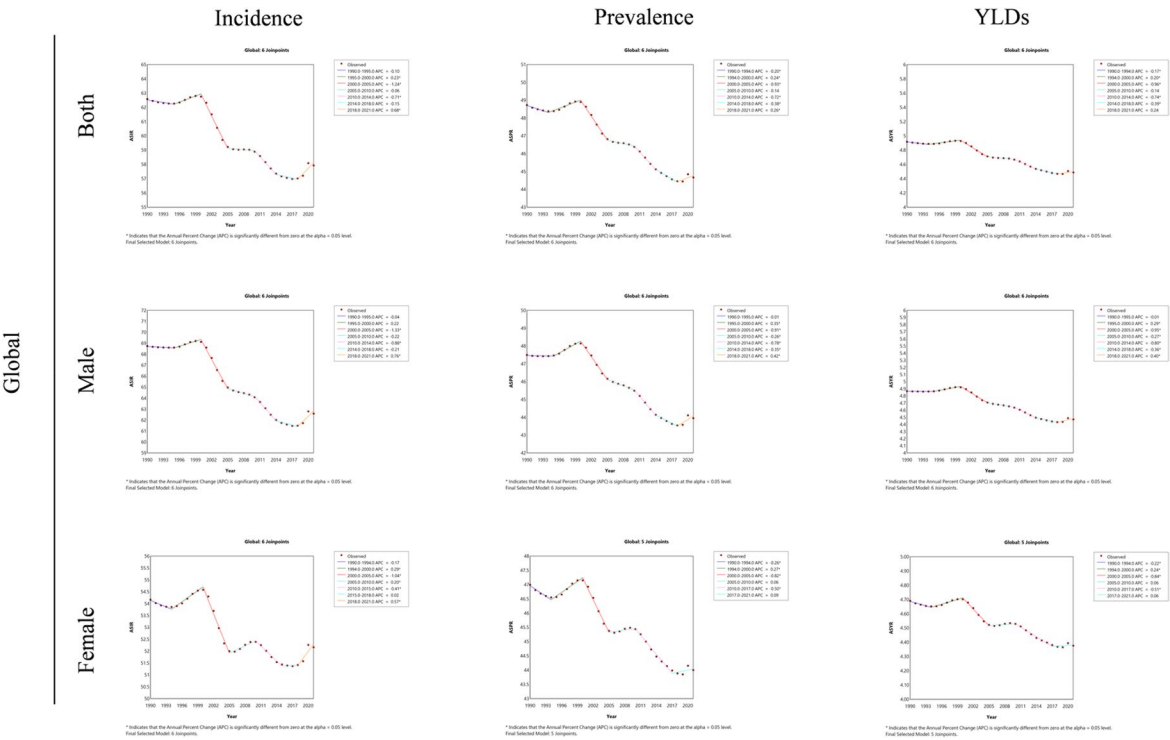

Fig. 2 Joinpoint regression analysis of the global ASIR, ASPR, and ASYR for VFs caused by falls for males, females, and both sexes during 1990–2021. *$p < 0.05$

Table 2 Original AAPCs and adjusted AAPCs of incidence, prevalence and YLDs for VFs in China and globally

Region	Indicator	1990 Adjusted Rate*(95% UI)	2021 Adjusted Rate*(95% UI)	Original AAPC (95% CI)	Adjusted AAPC (95% CI)	*P*–Value
China	Incidence	38.57 (19.70–68.25)	52.78 (27.60–93.39)	1.168 (0.804 to 1.534)	1.168 (0.802 to 1.535)	<0.001
	Prevalence	19.66 (12.64–28.92)	27.99 (18.20–41.28)	1.278 (0.904 to 1.652)	1.278 (0.907 to 1.649)	<0.001
	YLDs	2.04 (1.05–3.54)	2.88 (1.48–5.02)	1.247 (0.881 to 1.615)	1.247 (0.881 to 1.614)	<0.001
Global	Incidence	62.58 (33.03–108.65)	57.93 (30.59–101.36)	−0.235 (−0.319 to −0.151)	−0.235 (−0.320 to −0.151)	<0.001
	Prevalence	48.73 (32.96–69.29)	44.67 (29.94–63.66)	−0.272 (−0.334 to −0.209)	−0.272 (−0.334 to −0.209)	<0.001
	YLDs	4.92 (2.56–8.28)	4.49 (2.33–7.58)	−0.286 (−0.348 to −0.224)	−0.286 (−0.348 to −0.224)	<0.001

The Adjusted Rate* indicates the age-standardised rate per 100,000 population, with the upper and lower limits of each indicator to ±20%

2021. It is evident that the burden of each of these metrics is significantly higher in 2021 than in 1990. In 1990, the number of new incident cases in China and globally was observed mainly in the younger population. In contrast, most new cases in 2021 were observed in the middle-aged and elderly populations. The crude incidence rate (CIR) initially increased but then declined with age in 1990, whereas a gradual rising trend in the CIR was observed with age in 2021 (Fig. 3, panel A). Similar trends in the global CIR for VFs were observed in 1990 and 2021 (Fig. 3, panel B). In 2021, the new prevalence and YLD cases for VFs were notably greater than in 1990 in China, with most cases observed in the elderly population (Fig. 3, panels C, E). Furthermore, the crude prevalence rate (CPR), and crude YLD rate (CYR) all exhibited an increasing trend with age, both in 1990 and 2021. Similar global trends and crude rates of prevalence and YLDs for VFs were observed in 1990 and 2021 (Fig. 3, panels D, F).

Gender differences in the burden of VFs caused by falls across age groups in China and globally in 1990 and 2021

Figures 4 and 5 illustrate the burden of VFs caused by falls across different age groups for both males and females in China and globally in 1990 and 2021. In China, the incidence was highest among the younger population (aged 15–39) in 1990. In 2021, the number of cases significantly increased compared to 1990 and was mainly observed among the middle-aged and elderly population. In both 1990 and 2021, the incidence of VFs was higher among females than among males for those aged 65 years and older (Fig. 4, panels A, B). Globally, the number of incidence cases is notably higher in 2021 compared with 1990, particularly in the older age groups. The incidence of VFs among females surpassed that among males across all age groups for those aged 60 years and older in both 1990 and 2021 (Fig. 5, panels A, B). In China, there was a notable increase in prevalence in 2021 compared to 1990, with a particularly rapid increase among the elderly population. In 1990, the number of prevalent cases was higher in males under the age of 65, but higher in females aged 65 and above. In 2021, the prevalence was higher in females aged 75 years and older (Fig. 4, panels C, D). A significant increase in prevalence was observed globally in 2021 compared to 1990, particularly among the elderly population. The number of prevalence cases was higher in males younger than 65 years, but higher in females aged 65 years and older in both 1990 and 2021 (Fig. 5, panels C, D). In 2021, the YLDs increased significantly in China compared to 1990, with a rapid increase among the elderly population. In 1990, the YLDs were higher in males younger than 65 years but higher in females aged 65 years and older. In 2021, the YLDs were higher in females aged 75 years and older (Fig. 4, panels E, F). Similar trends can be observed for global YLDs (Fig. 5, panels E, F).

APC model analysis of the incidence of VFs caused by falls in China

Figure 6 shows the trends in the incidence of VFs across various age groups, birth cohorts, and time periods in China. It can be observed that the overall incidence of VFs generally increased with age, regardless of the time period (Fig. 6, panel A). Meanwhile, the earlier birth cohort exhibited a lower incidence rate at younger ages, but this rate increased rapidly with age. In contrast, the later birth cohort demonstrated a relatively higher incidence rate, with this rate increasing even more with age (Fig. 6, panel B). Additionally, the incidence rates were observed to be lower in the younger age groups, while in the older age groups, they were found to be high and increasing (Fig. 6, panel C). Furthermore, the incidence rates were relatively higher in older age groups in later birth cohorts, with a clear increasing trend as the birth

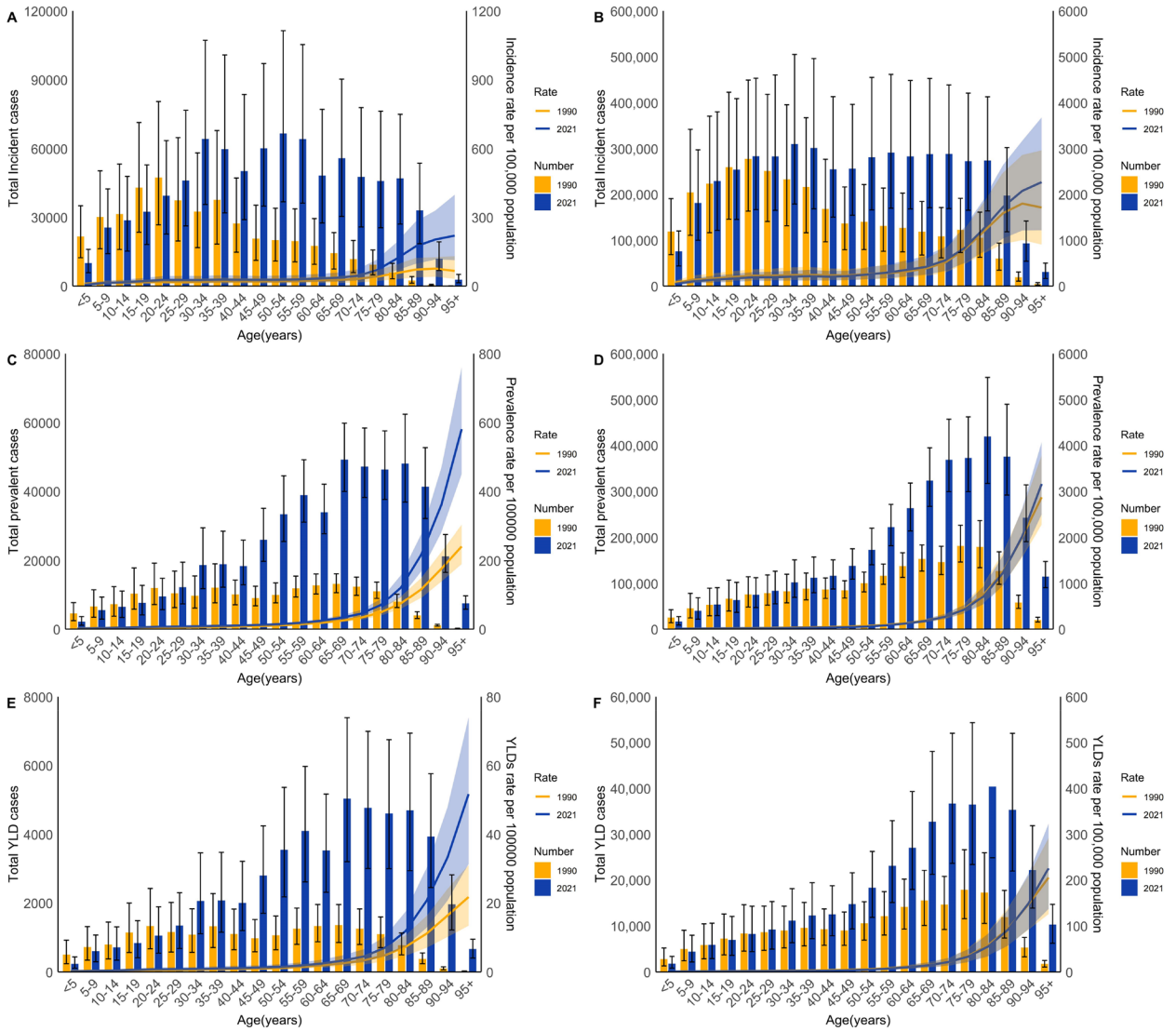

Fig. 3 Comparison of incidence, prevalence, and YLD cases and their crude rates per 100,000 population across different age groups in China and globally in 1990 and 2021. (**A**, **C**, **E**) Trends in China. (**B**, **D**, **F**) Global trends. Bar graphs illustrate counts, and lines illustrate crude rates. 1990 was shown in orange and 2021 in blue

cohort progressed (Fig. 6, panel D). Supplementary Fig. 1 and 2 illustrate a similar pattern in prevalence and YLD rates, which are also on a generally increasing trend with age.

Discussion

This study presented a detailed comparison of the incidence, prevalence, and YLDs related to VFs caused by falls in China and globally along with their temporal trends during 1990–2021 using data from the GBD Study 2021. In this analysis, we selected falls as the sole cause of VFs. Focusing on the effect of falls on VFs enables a more precise assessment of the impact of this risk factor on different populations, thereby enhancing the accuracy of the results.

The results of this study indicated an overall increase in the ASIR, ASPR and ASYR of VFs caused by falls in China from 1990 to 2021. This may be attributed to many reasons, including social, environmental or healthcare-related factors. First of all, China has the largest elderly population in the world. Given that older individuals are more susceptible to falls, this directly contributes to the risk of VFs [20]. Furthermore, as more Chinese individuals reside in urban areas, the risk of falls in these environments is increasing. Falls resulting from factors such as slippery floors, uneven surfaces, and high floors have

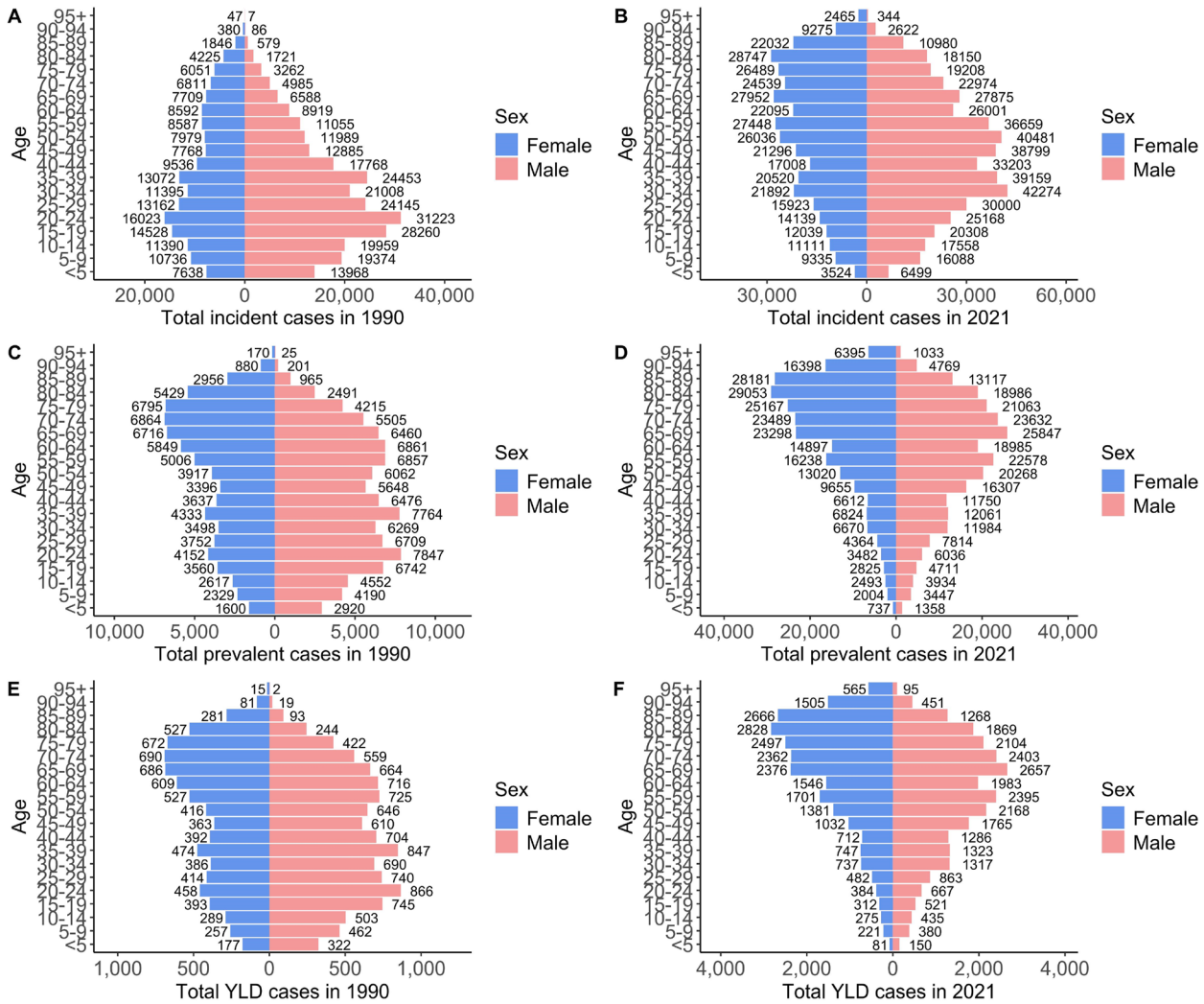

Fig. 4 Comparison of total cases of the incidence, prevalence, and YLDs of VFs caused by falls in males and females across different age groups in China in 1990 and 2021. The male was represented in red and the female in blue

the potential to cause VFs. Secondly, China's healthcare resources are distributed unevenly, with a notable lack of quality and accessibility in rural and remote areas. This has resulted in a delay in the diagnosis and treatment of falls-caused VFs among patients in these regions. In addition, enhancements in data reporting and monitoring systems may have led to the inclusion of previously unrecorded vertebral fracture cases in the statistics, thereby increasing the burden. However, the global ASIR, ASPR, and ASYR for VFs resulting from falls exhibited an overall decline from 1990 to 2021, which was contrary to our expected results. The reasons are as follows. Firstly, the global population increased significantly by 47.2% (from 5.3 billion to 7.8 billion) from 1990 to 2021 [21]. The notable increase in the number of young people may account for the declining global trend, as young people are less likely to suffer VFs resulting from falls. Secondly, the term "Global" as used in the GBD study denotes the overall global levels of disease burden rather than not referring to specific regions or countries. This is the fact that some regions and countries exhibit an increasing trend, while others exhibit a decreasing trend. It is reasonable to assume that countries with decreasing trends of falls-caused VFs may offset the impact of countries with increasing trends, thereby contributing to an overall global decline trend between 1990 and 2021.

In terms of gender, the study demonstrated that the ASIR, ASPR, and ASYR of VFs caused by falls were higher in males than in females, both in China and globally. This discrepancy may be attributed to the fact that a relatively higher proportion of males than females are engaged in high-risk physical work (e.g., construction) and strenuous exercise. These environments are complex and dangerous, with a high risk of injury from falls, which

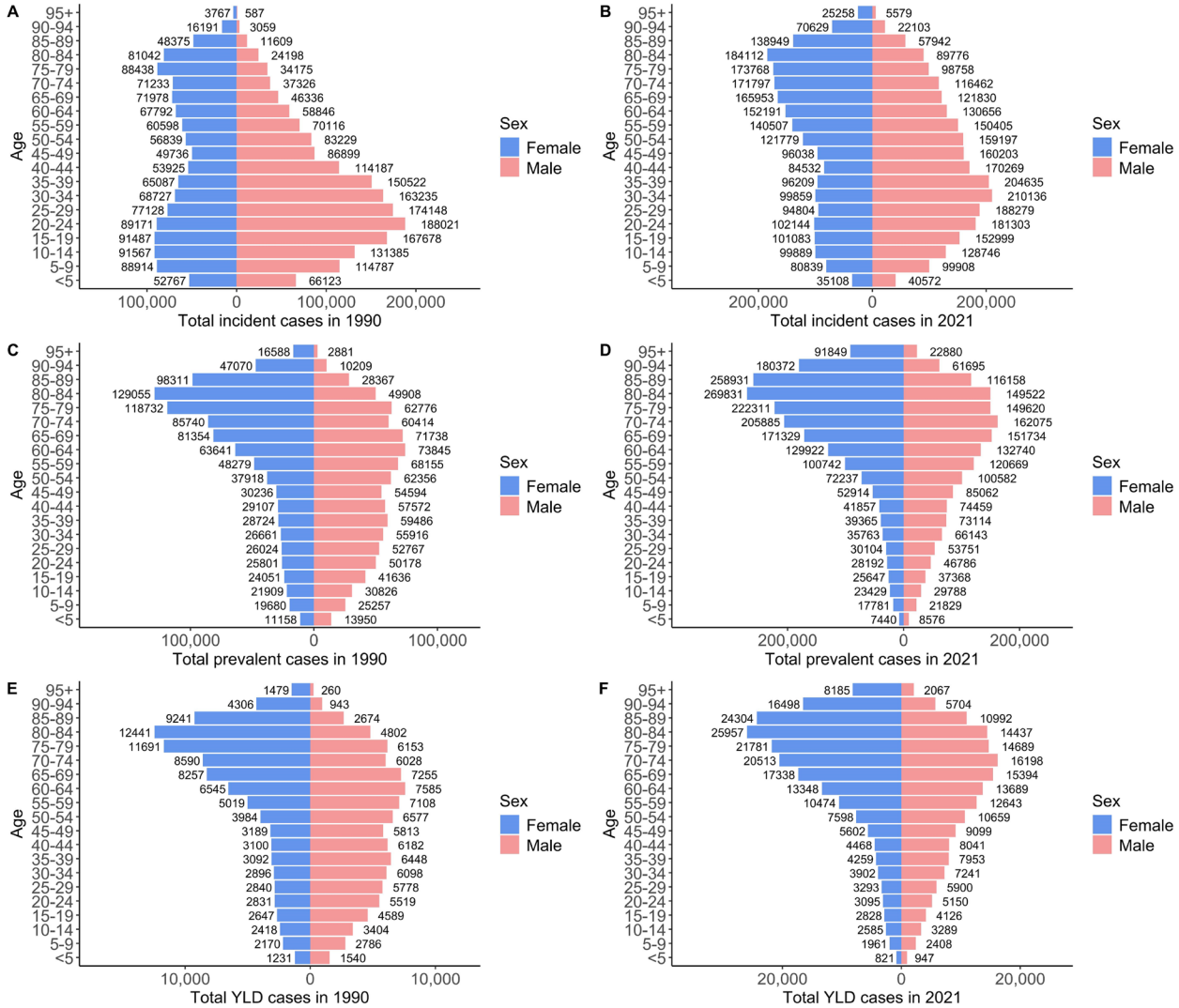

Fig. 5 Comparison of total cases of the global incidence, prevalence, and YLDs of VFs caused by falls in males and females across different age groups in 1990 and 2021. The male was represented in red and the female in blue

will increase the likelihood of VFs among males, leading to a higher overall disease burden. Regarding gender and age groups, the burden is heavier for the older population in China and globally, and the burden is higher for the older female population than for the older male population. The reasons may be as follows. First of all, oestrogen is of critical importance in maintaining bone density and bone health, and oestrogen levels decline dramatically in older females after menopause [7]. Reduction in oestrogen levels increases the likelihood of developing osteoporosis in females, thereby rendering them more vulnerable to falls and VFs [22]. Furthermore, sexual dimorphism, or the specific differences of sex, has been identified as an explanation for the greater susceptibility of females to osteoporosis compared to males [23]. This increases the possibility of older females suffering falls and VFs.

The APC analysis examined trends in the incidence, prevalence, and YLDs associated with VFs in China. Notably, the most significant increases in disease burden were observed in older age groups and the later birth cohorts. These patterns may be influenced by factors such as population ageing, and social-environmental changes in China over the past few decades. In conclusion, the results highlight the complex dynamics of VF metrics, revealing an increasing trend in incidence, prevalence, and YLDs.

At present, both global and Chinese populations are witnessing an ageing process [21]. In 2020, the World Health Organisation (WHO) and its Member States

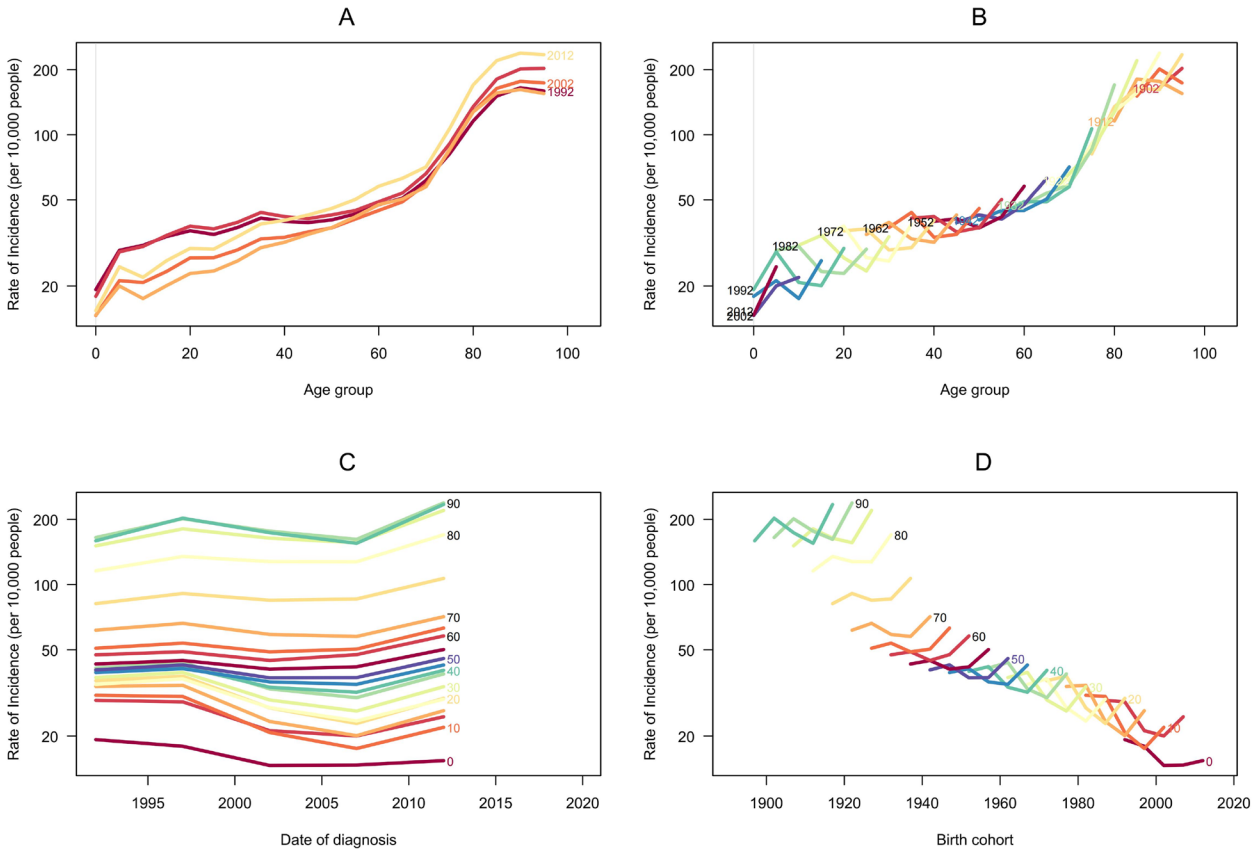

Fig. 6 Age, period, and cohort effects on the incidence of VFs in China. **A** Age-specific incidence rates of VFs across different time periods; each line represents the incidence for a 5-year interval. **B** Age-specific incidence rates of VFs by birth cohort; each line represents the incidence for a 5-year cohort. **C** Period-specific incidence rates of VFs by age groups; each line represents the incidence for a 5-year age group. **D** Birth cohort-specific incidence rates of VFs by age groups; each line represents the incidence for a 5-year age group

declared 2021–2030 as "The Decade of Healthy Ageing" to improve the health and quality of life of the elderly in the present and future. Concurrently, the Chinese government has implemented the "Healthy China 2030 Action Initiative" [24], which prioritises the health of the elderly. However, the rate of ageing in China is more rapid, which challenges its healthcare services. As the elderly population rises, so does the demand for medical resources, particularly in rural and remote areas, where the issue of unequal distribution of such resources is more pronounced. Meanwhile, as life expectancy increases, the number of older individuals requiring long-term care also increases, thereby placing greater demands on family and social care resources. Furthermore, older people are more susceptible to acute medical incidents, such as VFs caused by falls. Thus, targeted measures are crucial to address these issues. The Chinese government should augment its financial support and medical resources in rural and remote regions via policy guidance to enhance the quality and accessibility of medical services in these areas. Concurrently, the establishment and improvement of geriatric and long-term care systems should be promoted to reduce the burden of care on families and society and improve the quality of life of the elderly. Furthermore, it is necessary to reinforce the construction of emergency medical care systems and enhance the efficiency of emergency response for elderly individuals experiencing acute incidents. Finally, collaboration between the government, medical institutions, communities and families should be promoted, to establish a comprehensive health protection system for the elderly.

Osteoporosis is a condition that results in the deterioration of bone strength and structure, leading to fragility and an increased risk of fractures. VFs are typical fractures in osteoporosis [25]. An epidemiological study on osteoporosis in China found that the incidence of osteoporotic fractures steadily increased across mainland China [26]. The study also revealed a higher prevalence among females, older age groups, and residents of

northern regions in China. It is therefore imperative that effective measures be taken to address the issue of osteoporosis in China, to reduce the risk of VFs. One research demonstrated exercise programmes that incorporate balance, functional and resistance training as efficacious interventions for reducing falls in older adults [27]. Moreover, implementing the "5E" injury prevention strategy in six pilot villages in two Chinese provinces has demonstrated a decrease in both the occurrence of falls and the probability of subsequent falls [28]. The successful experience could be extended to the whole country. Furthermore, the utilisation of advanced diagnostic techniques, including dual-energy X-ray absorptiometry (DXA), computed tomography (CT), and magnetic resonance imaging (MRI), enables the precise assessment of bone density and bone health [29]. This has facilitated the early identification of osteoporosis, allowing for timely interventions to reduce the risk of VFs before the manifestation of symptoms. Concurrently, the use of bisphosphonates, bone-forming drugs (such as denosumab and teriparatide) and novel regenerative medicine treatments such as cell therapies and bioactive hydrogels, has been demonstrated to be efficacious in the treatment of osteoporosis [30, 31].

The Fracture Liaison Service (FLS) plays a crucial role in the management of fractures. FLS is a systematic method aimed at improving the quality of life of patients with osteoporosis, which has been proven to prevent subsequent fractures, as well as reduce mortality and cost-effectiveness [32]. FLS is typically implemented by a multidisciplinary team including doctors, nurses, physiotherapists and others, who collaborate to ensure the coordination and efficacy of patient care [33]. In China, the concept and practice of FLS are gradually being promoted and applied. It is anticipated that the FLS will become more widespread in China by raising public awareness, strengthening the training of healthcare professionals, and optimising resource allocation and policy support. This will contribute to an improvement in the quality of life for people with osteoporosis.

The ageing situation in China is not optimistic, which will inevitably lead to an increase in the burdens borne by families and the public healthcare system [34]. To effectively address the challenges posed by China's rapidly ageing population, it is necessary to adopt multifaceted approaches that consider the burden of ageing and associated fall risks. It is recommended that channels such as television, radio, and social media be used to disseminate knowledge about the prevention and treatment of osteoporosis and related fractures. Furthermore, targeted public education activities, such as health fairs and online education programmes, should be conducted to raise public awareness of osteoporosis and VFs. It is also advised that continuing medical education programmes be provided for medical professionals on the latest advances in the diagnosis and treatment of osteoporosis and its complications. Finally, multidisciplinary teamwork, including orthopaedics, endocrinology, geriatrics, and rehabilitation, should be encouraged to work together to provide comprehensive care for patients with VFs.

Limitations

This study faced several limitations that should be acknowledged. The quality of GBD data depends on the completeness and consistency of raw data across regions. In some areas, such as rural and remote regions of China, disease surveillance data coverage is limited, which may result in estimates that differ from the actual situation. In addition, differences in disease coding standards and data collection methods between countries and regions may further increase data uncertainty. It is therefore recommended that caution be exercised when concluding the GBD database, and that the importance of validating GBD results with the original data from other sources should be emphasised.

The accuracy of the DisMod-MR model is dependent on data quality. The model estimates may be insufficiently precise in areas where data are scarce or of low quality. This may result in deviations in model outputs from the actual situation. In addition, the DisMod-MR model is based on predefined model structures and parameters, which may constrain their adaptability to emerging health issues or rapidly changing data, particularly in the case of rapidly evolving disease prevalence trends, the model may not be able to capture these shifts promptly. It is recommended that future studies employ various models for comparative analyses, thereby reducing reliance on the output of a single model and enhancing the reliability of the estimates.

Furthermore, in the past decades, the development of imaging technologies in China, particularly the application of artificial intelligence in diagnostic imaging, possibly has had a significant impact on the diagnosis rate of VFs [35, 36]. This technological progress may artificially inflate incidence and prevalence rates, rather than reflecting a true change in disease burden. It is recommended that future studies should develop and adapt statistical models to correct for any potential biases that may be introduced by advances in imaging technology.

Conclusions

This study utilised the GBD 2021 database to comprehensively analyse trends in VFs resulting from falls in China and globally by gender and age. The results demonstrated an unequal distribution of disease burdens between

China and worldwide, as well as divergent trends over time. However, it is important to acknowledge the inherent limitations of the GBD database and the DisMod-MR model. Consequently, our findings should be understood with caution, and regional realities must be taken into account when implementing specific interventions. Future researchers should employ the data critically and integrate evidence from other sources to develop more comprehensive and effective health strategies. In conclusion, the GBD 2021 database provides a robust tool for understanding and addressing the burden of falls-caused VFs in China and globally.

Abbreviations

VFs	Vertebral fractures
GBD	Global Burden of Disease
YLDs	Years lived with disability
ASIR	Age-standardised incidence rate
ASPR	Age-standardised prevalence rate
ASYR	Age-standardised YLD rate
CIR	Crude incidence rate per 100,000 population
CPR	Crude prevalence rate per 100,000 population
CYR	Crude years lived with disability rate per 100,000 population
AAPC	Average annual percentage change
APC	Age-period-cohort
UI	Uncertainty interval
CI	Confidence interval

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13690-025-01500-y.

Supplementary Material 1

Acknowledgements
We would like to acknowledge the IHME for granting open access to their resources. Our sincere gratitude extends to the anonymous reviewers for their insightful feedback and constructive suggestions. Additionally, we are grateful to LetPub (https://www.letpub.com.cn) for its professional linguistic assistance during the preparation of this manuscript.

Authors' contributions
ZL contributed to the study design, data collection, interpretation, and analysis, and drafted and revised the manuscript. CL contributed to the data interpretation and analysis and drafted the manuscript. HW contributed to the data interpretation and analysis and drafted the manuscript. YW contributed to the data interpretation and analysis and drafted the manuscript. SK contributed to the data interpretation and analysis and drafted the manuscript. YJ contributed to the data interpretation and analysis and drafted the manuscript. YD was involved in the study design, data collection, interpretation, and analysis, and played a critical role in revising and reviewing the manuscript. All the authors reviewed and approved the final manuscript.

Funding
This work was supported by the Anhui Province Traditional Chinese Medicine Inheritance and Innovation Research Project (2024CCCX287). Grant fund was used to support data analysis activities, including software acquisition, computing resource rental, and labour costs for data analysts. Furthermore, funding facilitated the manuscript writing and publication process, including the engagement of professional editing services to enhance the manuscript's quality and the payment of open-access publishing fees to guarantee the widest possible accessibility to the findings.

Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Received: 31 October 2024 Accepted: 2 January 2025
Published online: 17 February 2025

References

1. Wood KB, Li W, Lebl DR, Ploumis A. Management of thoracolumbar spine fractures. Spine J. 2014;14(1):145–64.
2. Saul D, Dresing K. Epidemiology of VFs in pediatric and adolescent patients. Pediatr Rep. 2018;10(1):7232.
3. LeBoff MS, Greenspan SL, Insogna KL, Lewiecki EM, Saag KG, Singer AJ, et al. The clinician's guide to prevention and treatment of osteoporosis. Osteoporos Int. 2022;33(10):2049–102.
4. Damron TA, Mann KA. Fracture risk assessment and clinical decision making for patients with metastatic bone disease. J Orthop Res. 2020;38(6):1175–90.
5. Choi HG, Lee JK, Sim S, Kim M. Mortality and Cause of Death in Patients With VFs: A Longitudinal Follow-Up Study Using a National Sample Cohort. Spine (Phila Pa 1976). 2020;45(5):E280–7.
6. Skjødt MK, Abrahamsen B. New Insights in the Pathophysiology, Epidemiology, and Response to Treatment of Osteoporotic VFs. J Clin Endocrinol Metab. 2023;108(11):e1175–85.
7. Clarke BL, Khosla S. Female reproductive system and bone. Arch Biochem Biophys. 2010;503(1):118–28.
8. Ballane G, Cauley JA, Luckey MM, El-Hajj FG. Worldwide prevalence and incidence of osteoporotic VFs. Osteoporos Int. 2017;28(5):1531–42.
9. Wang L, Yu W, Yin X, Cui L, Tang S, Jiang N, et al. Prevalence of Osteoporosis and Fracture in China: The China Osteoporosis Prevalence Study. JAMA Netw Open. 2021;4(8):e2121106.
10. Sanfélix-Genovés J, Reig-Molla B, Sanfélix-Gimeno G, Peiró S, Graells-Ferrer M, Vega-Martínez M, et al. The population-based prevalence of osteoporotic vertebral fracture and densitometric osteoporosis in postmenopausal females over 50 in Valencia, Spain (the FRAVO study). Bone. 2010;47(3):610–6.
11. GBD 2021 Diseases and Injuries Collaborators. 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. 2024;403(10440):2133–2161.
12. GBD 2021 Risk Factors Collaborators. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024;403(10440):2162–2203.
13. GBD 2019 Fracture Collaborators. Global, regional, and national burden of bone fractures in 204 countries and territories, 1990–2019: a systematic analysis from the Global Burden of Disease Study 2019. Lancet Healthy Longev. 2021;2(9):e580-e592.
14. Xu T, Dong W, Liu J, Yin P, Wang Z, Zhang L, et al. Disease burden of Parkinson's disease in China and its provinces from 1990 to 2021: findings from the global burden of disease study 2021. Lancet Reg Health West Pac. 2024;46:101078.
15. Ma Q, Li R, Wang L, Yin P, Wang Y, Yan C, et al. Temporal trend and attributable risk factors of stroke burden in China, 1990–2019: an analysis for the Global Burden of Disease Study 2019. Lancet Public Health. 2021;6(12):e897–906.
16. Luo L. Assessing validity and application scope of the intrinsic estimator approach to the age-period-cohort problem. Demography. 2013;50(6):1945–67.

17. Dong Y, Peng R, Kang H, Song K, Guo Q, Zhao H, et al. Global incidence, prevalence, and disability of VFs: a systematic analysis of the global burden of disease study 2019. Spine J. 2022;22(5):857–68.
18. Kim HJ, Chen HS, Byrne J, Wheeler B, Feuer EJ. Twenty years since Joinpoint 1.0: Two major enhancements, their justification, and impact. Stat Med. 2022;41(16):3102–30.
19. Qiu H, Cao S, Xu R. Cancer incidence, mortality, and burden in China: a time-trend analysis and comparison with the United States and the United Kingdom based on the global epide-miological data released in 2020. Cancer Commun (Lond). 2021;41(10):1037–48.
20. Fu Y, Ba L, Lü N, Yang H, Hong X, Zhou J, et al. Burden of falls attributable to low bone mineral density among people aged 60 years and over in China from 1990 to 2019. Front Public Health. 2023;11:1204497.
21. GBD 2021 Fertility and Forecasting Collaborators. Global fertility in 204 countries and territories, 1950–2021, with forecasts to 2100: a comprehensive demographic analysis for the Global Burden of Disease Study 2021. Lancet. 2024;403(10440):2057–2099.
22. Almeida M, Laurent MR, Dubois V, Claessens F, O'Brien CA, Bouillon R, et al. Estrogens and Androgens in Skeletal Physiology and Pathophysiology. Physiol Rev. 2017;97(1):135–87.
23. Zhang YY, Xie N, Sun XD, Nice EC, Liou YC, Huang C, et al. Insights and implications of sexual dimorphism in osteoporosis. Bone Res. 2024;12(1):8.
24. Chen P, Li F, Harmer P. Healthy China 2030: moving from blueprint to action with a new focus on public health. Lancet Public Health. 2019;4(9):e447.
25. Gregson CL, Armstrong DJ, Bowden J, Cooper C, Edwards J, Gittoes NJL, et al. UK clinical guideline for the prevention and treatment of osteoporosis. Arch Osteoporos. 2022;17(1):58.
26. Yu F, Xia W. The epidemiology of osteoporosis, associated fragility fractures, and management gap in China. Arch Osteoporos. 2019;14(1):32.
27. Sherrington C, Fairhall NJ, Wallbank GK, Tiedemann A, Michaleff ZA, Howard K, et al. Exercise for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2019;1(1):CD012424.
28. Sun F, Luo R, Han H. Evaluation of the Effectiveness of "5E" Comprehensive Injury Prevention Strategy for Fall Prevention Among the Rural Elderly - Six Pilot Villages, Yunnan Province and Chongqing Municipality, China, 2018–2023. China CDC Wkly. 2024;6(14):277–81.
29. Lewiecki EM. Assessment of Skeletal Strength: Bone Density Testing and Beyond. Endocrinol Metab Clin North Am. 2021;50(2):299–317.
30. Ayers C, Kansagara D, Lazur B, Fu R, Kwon A, Harrod C. Effectiveness and Safety of Treatments to Prevent Fractures in People With Low Bone Mass or Primary Osteoporosis: A Living Systematic Review and Network Meta-analysis for the American College of Physicians. Ann Intern Med. 2023;176(2):182–95.
31. Aibar-Almazán A, Voltes-Martínez A, Castellote-Caballero Y, Afanador-Restrepo DF, Carcelén-Fraile MDC, López-Ruiz E. Current Status of the Diagnosis and Management of Osteoporosis. Int J Mol Sci. 2022;23(16):9465.
32. Briot K. Fracture Liaison Services. Curr Opin Rheumatol. 2017;29(4):416–21.
33. Geusens P, Bours SPG, Wyers CE, van den Bergh JP. Fracture liaison programs. Best Pract Res Clin Rheumatol. 2019;33(2):278–89.
34. Fang EF, Xie C, Schenkel JA, Wu C, Long Q, Cui H, et al. A research agenda for ageing in China in the 21st century (2nd edition): Focusing on basic and translational research, long-term care, policy and social networks. Ageing Res Rev. 2020;64:101174.
35. Shen L, Gao C, Hu S, Kang D, Zhang Z, Xia D, et al. Using Artificial Intelligence to Diagnose Osteoporotic VFs on Plain Radiographs. J Bone Miner Res. 2023;38(9):1278–87.
36. Li WG, Zeng R, Lu Y, Li WX, Wang TT, Lin H, et al. The value of radiomics-based CT combined with machine learning in the diagnosis of occult VFs. BMC Musculoskelet Disord. 2023;24(1):819.

Publisher's Note