


# Global Trends in the Incidence and Primary Causes of Femoral Fractures, Excluding Femoral Neck Fractures: A Global Epidemiological Study

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**Purpose:** Fractures pose a significant global health challenge, with varying incidence trends and causes across demographics and regions. This study aims to analyze global patterns in the incidence and primary causes of femoral shaft fractures.

**Methods:** Data from the Global Burden of Disease database were analyzed for femoral fractures (excluding femoral neck fractures) by age, gender, and socio-demographic index regions. The estimated annual percentage change (EAPC) was calculated to assess trends in the incidence of femoral shaft fractures.

**Results:** Global femoral fracture cases increased from 8,559,886 in 1990 to 11,566,429 in 2021, a rise of 35.12%. However, the incidence rate dropped from 160.49 to 146.57 per 100,000 (EAPC: -0.35). Males consistently had higher rates, reaching 155.53 per 100,000 in 2021. The 15–49 age group recorded the most cases, while individuals aged 75 and older saw the largest rise in incidence, from 445.91 to 603.32 per 100,000. In 2021, Slovenia (616.1 per 100,000), Croatia (568.51 per 100,000), and Czechia (434.77 per 100,000) reported the highest rates, while Malawi, Kiribati, and Liberia had the lowest (<63 per 100,000). Leading causes were mechanical forces, motor vehicle injuries, and pedestrian injuries, with notable regional disparities.

**Conclusion:** Although the global incidence rate of femoral shaft fractures has declined, it has risen significantly among older adults, increasing their burden. Understanding regional variations in causes is crucial for developing targeted public health interventions to address this growing issue.

**Keywords:** femoral shaft fractures, global epidemiology, incidence, injury

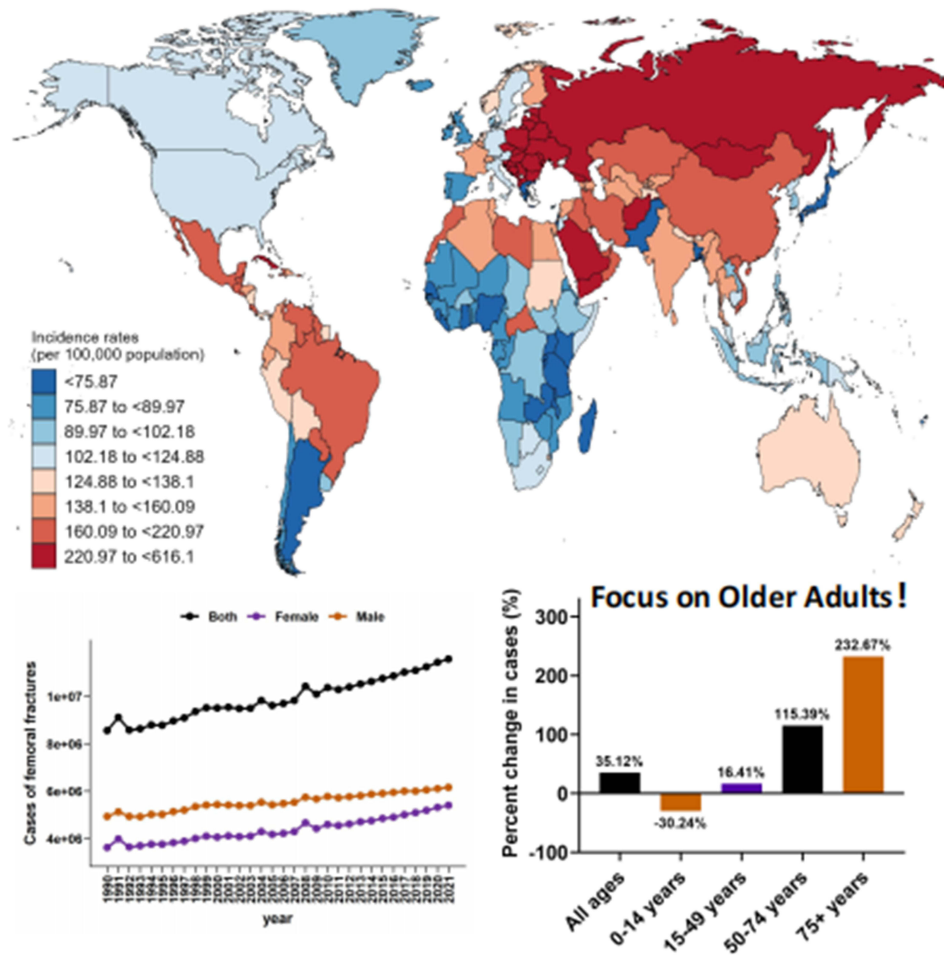
## Introduction

Femoral fractures are a serious type of bone injury, particularly prevalent among the elderly, with their incidence increasing globally.<sup>1</sup> According to statistics from the World Health Organization, femoral fractures not only impact patients' physical functionality but can also lead to long-term disability, chronic pain, and mental health issues.<sup>2</sup> Therefore, studying the epidemiological characteristics and causative factors of femoral fractures is crucial for developing effective prevention and intervention measures.

The occurrence of femoral shaft fractures typically requires significant external force and, compared to other types of fractures (such as wrist and vertebral fractures), their recovery process is more complex.<sup>3</sup> Wrist fractures are more common among younger individuals, often resulting from sports or accidents, while femoral shaft fractures primarily occur in older adults, especially due to falls.<sup>4</sup> Older individuals are more susceptible to such fractures due to decreased bone density and balance

## Graphical Abstract

## Global Trends in Femoral Fracture Incidence



ability.<sup>4,5</sup> Globally, the incidence of femoral shaft fractures varies significantly.<sup>6</sup> In developed countries, fracture rates are generally higher, continuing to rise with the increasing proportion of elderly individuals and changing lifestyles.<sup>7,8</sup> In contrast, although the absolute incidence is lower in developing countries, urbanization and lifestyle changes are also contributing to its increase.<sup>9</sup> Various factors influence the occurrence of femoral shaft fractures, including age, gender, bone density, nutritional status, and socioeconomic conditions.<sup>10</sup> Additionally, dietary habits, living environments, and accessibility to medical resources in different regions also impact fracture occurrence rates.<sup>11</sup>

As global aging accelerates, the issues of prevention and management of will become increasingly prominent. It is projected that by 2030, the global population aged 60 and above will reach 1.3 billion, posing significant pressure on healthcare systems and social resources.<sup>12</sup> Therefore, systematic research on the epidemiological trends and primary causative factors of is essential for identifying high-risk populations, assessing intervention effects, and formulating public health policies. This study utilizes the Global Burden of Disease (GBD) 2021 data to analyze the trends in the incidence of, other than femoral neck fractures, from 1990 to 2021, revealing the primary causes of across different ages, genders, and regions. The aim is to provide scientific evidence for effective prevention and treatment strategies, helping to address the increasingly severe public health challenges.

## Methods

### Data Source

This study utilized data from the Global Burden of Disease (GBD) 2021 database to analyze the trends in the incidence of femoral fractures, excluding femoral neck fractures, from 1990 to 2021.<sup>13</sup> In this study, “femoral fractures” specifically refers to fractures of the femur excluding the femoral neck. The GBD database compiles a wide range of health data from various sources, including vital registration systems, health surveys, and epidemiological studies.<sup>14</sup> It provides comprehensive epidemiological data across various countries and regions, including information on disease incidence, prevalence, mortality, and disability-adjusted life years (DALYs).<sup>15</sup>

For this study, we specifically extracted data categorized by gender (male and female) and age groups (0–14, 15–49, 50–74, and 75+ years). Additionally, data were analyzed based on five Socio-Demographic Index (SDI) regions and 21 geographical regions to facilitate a thorough comparative analysis. The database also includes data on the primary causes leading to femoral fractures, enabling an in-depth exploration of risk factors associated with this injury.<sup>15</sup>

### Statistical Analysis

Incidence rates of femoral fractures were calculated per 100,000 individuals by dividing the number of new cases by the population during the specified time period and then multiplying by 100,000. To assess trends over time, the annual percentage change (EAPC) was calculated using a linear regression model, assuming that the natural logarithm of rates is linear over time.<sup>16</sup> This relationship can be expressed as:  $\ln(\text{Rates}) = a + bX + \epsilon$ . The EAPC was computed using the formula of 100 times the exponential of the regression coefficient minus one (ie,  $\text{EAPC} = 100 \times (\exp(b) - 1)$ ). The EAPC indicates the direction and magnitude of trends in femoral fracture incidence over time; if the EAPC is greater than 0, it suggests an increasing trend, while a value less than 0 indicates a decreasing trend. The confidence interval (CI) provides a range of uncertainty around the EAPC estimate, allowing for a more nuanced interpretation of the data.<sup>16,17</sup>

The percent change in the number of cases between 1990 and 2021 was calculated as the difference between the number of cases in 2021 and those in 1990, divided by the number of cases in 1990 (ie,  $\text{Percent Change} = 100\% \times (\text{Cases in 2021} - \text{Cases in 1990}) / \text{Cases in 1990}$ ).<sup>17</sup> Descriptive statistics, including incidence rates and uncertainty intervals (UI), were used to summarize the data. Trends over time were analyzed using linear regression models to assess the significance of changes in incidence rates.

Statistical software such as R (version 4.1.0) was used for data manipulation and analysis, employing the “dplyr” and “ggplot2” packages for data handling and visualization. Since this study used publicly available aggregated data from the GBD database, ethical approval was not required. Data processing followed ethical standards, ensuring confidentiality and integrity. This approach provides a thorough understanding of global trends in femoral fracture incidence and highlights key causes and regional variations.

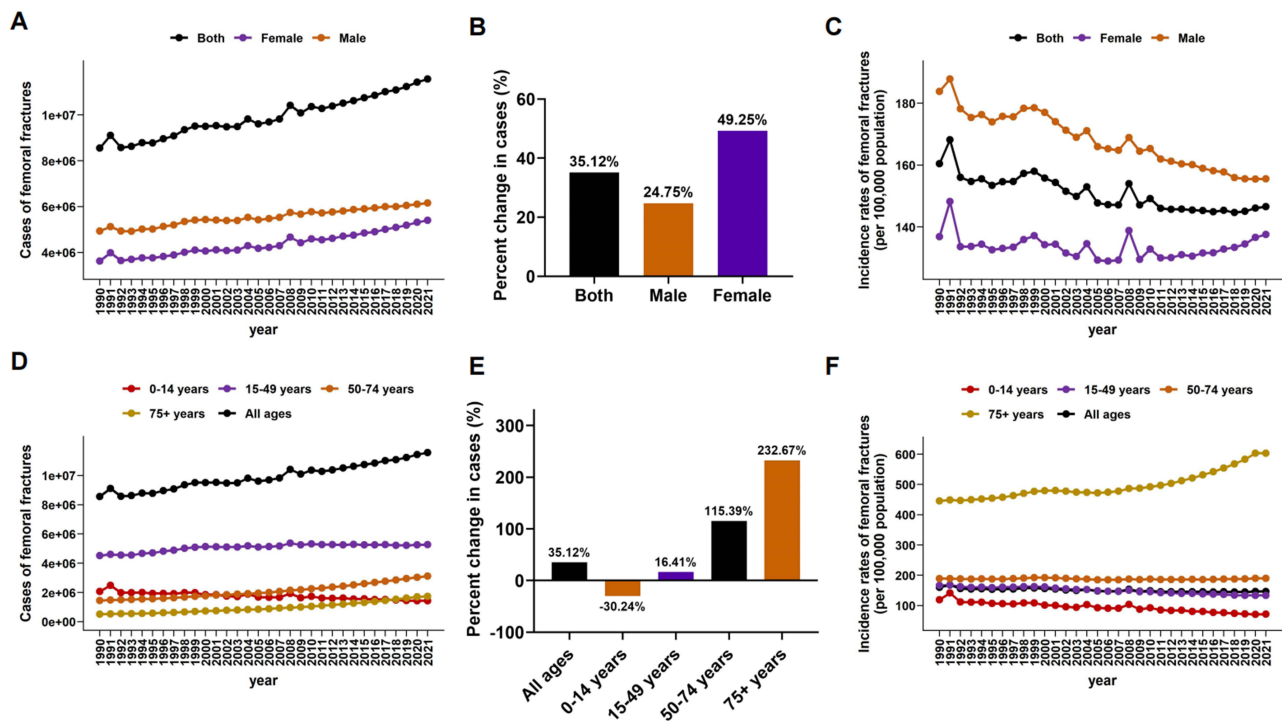
## Results

### Global Epidemiological Trends of Femoral Fractures

Globally, the number of femoral fracture cases increased from 8,559,886 in 1990 to 11,566,429 in 2021, reflecting a rise of 35.12% (Figure 1A and B and Table 1). However, the incidence rate of femoral fractures decreased from 160.49 per 100,000 in 1990 to 146.57 per 100,000 in 2021, with an EAPC of  $-0.35$  (Figure 1C and Table 1). Notably, while the burden of incidence is higher in males compared to females, the percentage change in new cases for females between 1990 and 2021 was significantly greater, increasing by 49.25% (Table 1). In 2021, the incidence rates of femoral fractures were 155.53 per 100,000 for males and 137.55 per 100,000 for females, with EAPCs of  $-0.55$  and  $-0.09$ , respectively (Table 1).

### Global Age Differences in Femoral Fractures

In terms of age group differences, the number of femoral fractures among individuals aged 15 to 49 remained the highest from 1990 to 2021. This group reached 5,264,939 cases in 2021; however, the increase was modest at 16.41% (Figure 1D and E and Table 1). Interestingly, the 0 to 14 age group was the only one to experience a decline, with cases decreasing



**Figure 1** Global epidemiological trends of femoral fractures (excluding femoral neck fractures) by age and sex. **(A)** New cases from 1990 to 2021 by sex. **(B)** Percentage change in cases between 1990 and 2021 by sex. **(C)** Incidence rates from 1990 to 2021 by sex. **(D)** New cases from 1990 to 2021 by age groups. **(E)** Percentage change in cases between 1990 and 2021 by age groups. **(F)** Incidence rates from 1990 to 2021 by age groups.

by 30.24% (Figure 1D, E and Table 1). This reduction may be attributed to advancements in care and management of children over the past decades, reflecting improved safety measures and healthcare practices. In contrast, the cases for individuals aged 50 to 74 and those aged 75 and older exhibited significant increases, rising by 115.39% and 232.67%, respectively (Figure 1D, E and Table 1). Consistent with other reports,<sup>18</sup> the incidence rate for the 75 and older group was notably high, increasing from 445.91 per 100,000 in 1990 to 603.32 per 100,000 in 2021. This age group had an EAPC of 0.87, which is approximately two to three times higher than that of other age groups (Figure 1F and Table 1). For the remaining age groups, specifically those aged 0 to 14, 15 to 49, and 50 to 74, the incidence rates in 2021 were 71.6 per 100,000, 133.34 per 100,000, and 189.98 per 100,000, respectively (Figure 1F and Table 1). Notably, all these age groups demonstrated a downward trend, with EAPCs of  $-1.68$ ,  $-0.76$ , and  $-0.03$  (Table 1), further emphasizing the shifting landscape of femoral fracture incidence across different age demographics.

## Geographical Distribution Characteristics of Femoral Fractures

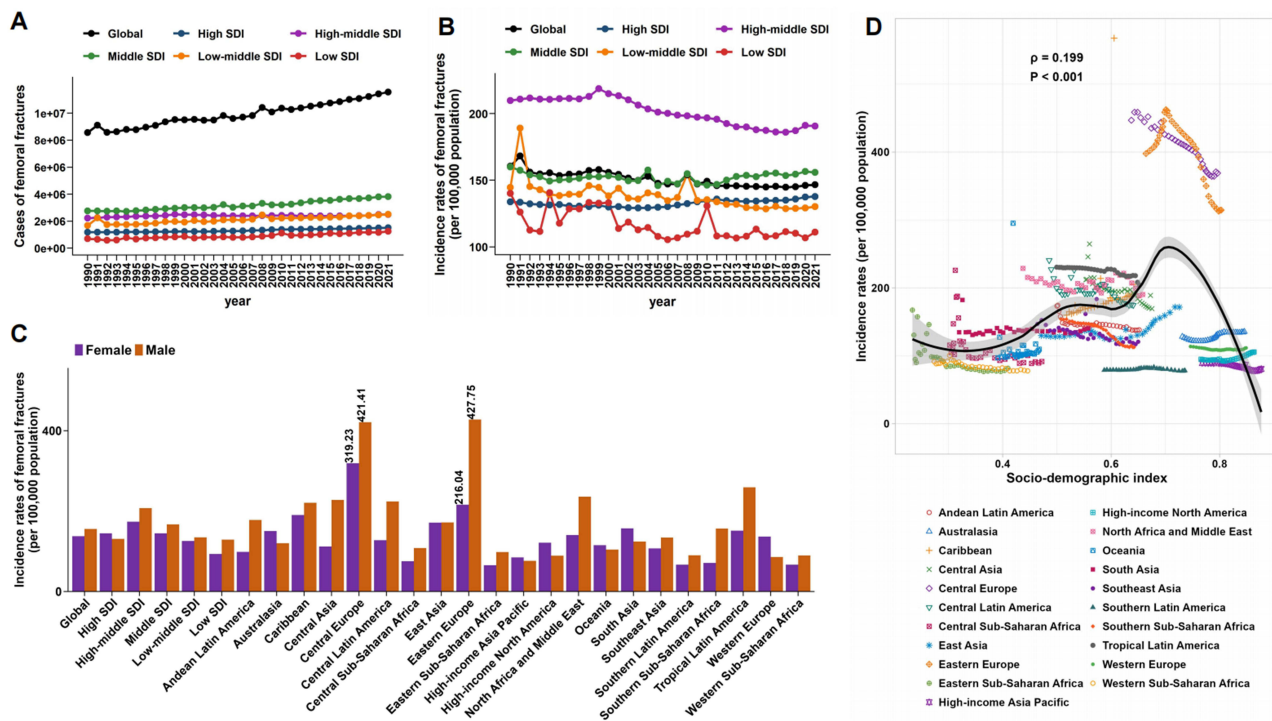
The distribution of femoral fracture incidence varies by geographical region, highlighting the complexity of this global health issue.<sup>7</sup> Between 1990 and 2021, the number of cases in all five SDI regions showed a steady increase, although the Low SDI region reported significantly fewer cases compared to the others (Figure 2A). In terms of incidence rates, fluctuations were more pronounced in certain years, likely influenced by specific events that affected health systems and reporting practices. In 2021, the incidence rates for the High SDI, High-middle SDI, Middle SDI, Low-middle SDI, and Low SDI regions were 137.78, 190.56, 155.91, 130.24, and 111.1 per 100,000, respectively (Figure 2B and Table 1).

While males generally exhibited higher incidence rates than females across all SDI regions, it is noteworthy that the trends showed little variation between genders (Supplementary Figure S1). Among the 21 geographical regions analyzed, the highest male incidence rates were found in Eastern Europe, Central Europe, and Tropical Latin America, with rates of 427.75, 421.41, and 259.32 per 100,000, respectively (Figure 2C). Conversely, the highest female incidence rates were observed in Central Europe, Eastern Europe, and the Caribbean, with rates of 319.22, 216.04, and 190.25 per 100,000 (Figure 2C).

**Table 1** Global Incidence of Femoral Fractures (Excluding Femoral Neck Fractures) from 1990 to 2021 and Their Trends

Characteristics	1990		2021		Cases_Change (%)	EAPC
	Cases, n	Incidence Rates, Per 100,000	Cases, n	Incidence Rates, Per 100,000		
<b>Global</b>	8559886(7018864 to 10645221)	160.49(131.6 to 199.59)	11,566,429(8890197 to 15048861)	146.57(112.66 to 190.7)	35.12(22.25 to 48.7)	-0.35(-0.41 to -0.28)
<b>Sex</b>						
Male	4936206(4078136 to 6089809)	183.79(151.84 to 226.75)	6,157,959(4982323 to 7777555)	155.53(125.84 to 196.43)	24.75(15.95 to 34.79)	-0.55(-0.6 to -0.5)
Female	3623680(2867566 to 4656549)	136.85(108.3 to 175.86)	5,408,470(3939064 to 7168481)	137.55(100.18 to 182.31)	49.25(31.01 to 67.15)	-0.09(-0.19 to 0.01)
<b>Ages</b>						
0–14 years	2065261(1651153 to 2607552)	118.75(94.94 to 149.93)	1,440,584(1143489 to 1800337)	71.6(56.84 to 89.49)	-30.25(-34.47 to -26.26)	-1.68(-1.87 to -1.5)
15–49 years	4522774(3681527 to 5672726)	166.86(135.83 to 209.29)	5,264,939(4205432 to 6745287)	133.34(106.5 to 170.83)	16.41(10.9 to 22.83)	-0.76(-0.82 to -0.71)
50–74 years	1448590(1067129 to 1934664)	188.95(139.19 to 252.35)	3,120,154(2227467 to 4196119)	189.98(135.62 to 255.49)	115.39(100.52 to 128.86)	-0.03(-0.07 to 0.01)
75+ years	523262(321977 to 797568)	445.91(274.38 to 679.67)	1,740,752(1030291 to 2649747)	603.32(357.08 to 918.36)	232.67(211.62 to 256.49)	0.87(0.74 to 0.99)
<b>SDI regions</b>						
High SDI	1176630(940097 to 1496314)	133.78(106.89 to 170.13)	1,507,363(1115679 to 1985991)	137.78(101.98 to 181.53)	28.11(13.21 to 42.35)	0.13(0.08 to 0.18)
High-middle SDI	2230949(1795430 to 2839506)	209.77(168.82 to 266.99)	2,484,921(1875990 to 3291249)	190.56(143.86 to 252.39)	11.38(-0.98 to 24.04)	-0.5(-0.58 to -0.43)
Middle SDI	2756464(2248382 to 3421892)	159.99(130.5 to 198.61)	3,817,416(2931566 to 5019015)	155.91(119.73 to 204.98)	38.49(21.12 to 56.71)	0(-0.08 to 0.09)
Low-middle SDI	1680216(1384281 to 2074399)	144.67(119.19 to 178.61)	2,502,115(1960940 to 3197811)	130.24(102.07 to 166.46)	48.92(37.05 to 61.22)	-0.53(-0.74 to -0.33)
Low SDI	702356(52697 to 919998)	140.11(110.25 to 183.52)	1,241,414(982280 to 1571670)	111.1(87.91 to 140.66)	76.75(63.06 to 90.71)	-0.62(-0.87 to -0.36)
<b>Location</b>						
Australasia	26000(20377 to 33419)	128.23(100.49 to 164.82)	41,948(31030 to 56533)	135.49(100.22 to 182.59)	61.34(38.23 to 88.97)	0.38(0.3 to 0.47)
Caribbean	56419(45023 to 72234)	159.86(127.57 to 204.67)	97,397(75532 to 126732)	205.23(159.15 to 267.04)	72.63(55.29 to 92.29)	0.76(-0.02 to 1.54)
Central Asia	146930(116387 to 189635)	211.98(167.92 to 273.6)	162,311(126602 to 211167)	169.41(132.14 to 220.4)	10.47(6.86 to 14.28)	-0.87(-1.06 to -0.68)
Central Europe	558988(426461 to 752568)	446.86(340.92 to 601.61)	425,345(305968 to 578007)	369.02(265.45 to 501.46)	-23.91(-30.67 to -17.58)	-0.79(-0.84 to -0.74)
Central Latin America	395518(311394 to 510985)	240.57(189.4 to 310.8)	441,612(346929 to 580715)	174.55(137.12 to 229.53)	11.65(4.86 to 17.93)	-0.6(-0.8 to -0.39)
Central Sub-Saharan Africa	63597(51687 to 77711)	115.71(94.04 to 141.39)	125,463(103565 to 151128)	91.63(75.63 to 110.37)	97.28(88.25 to 108.06)	-1.58(-2.27 to -0.89)
East Asia	1580211(1277865 to 2011859)	129.8(104.96 to 165.25)	2,528,208(1860909 to 3385632)	171.66(126.35 to 229.88)	59.99(35.8 to 85.13)	0.75(0.52 to 0.99)
Eastern Europe	900791(711762 to 1177691)	397.72(314.26 to 519.97)	650,343(502286 to 858443)	314.54(242.93 to 415.19)	-27.8(-33.45 to -22.16)	-1.06(-1.37 to -0.75)
Eastern Sub-Saharan Africa	319334(217980 to 495445)	167.34(114.23 to 259.63)	348,310(280587 to 439418)	81.74(65.85 to 103.13)	9.07(-21.48 to 43.28)	-1.85(-2.35 to -1.35)
High-income Asia Pacific	154837(124525 to 193921)	89.31(71.82 to 111.85)	149,630(111331 to 198633)	80.69(60.03 to 107.11)	-3.36(-18.89 to 14.53)	-0.51(-0.58 to -0.44)
High-income North America	267142(216482 to 336235)	94.93(76.93 to 119.48)	391,147(292463 to 514735)	105.67(79.01 to 139.05)	46.42(25.78 to 67.87)	0.35(0.24 to 0.45)
North Africa and Middle East	775834(622995 to 947250)	228.73(183.67 to 279.27)	1,185,064(955111 to 1457765)	190.22(153.31 to 233.99)	52.75(33.53 to 72.04)	-0.12(-0.29 to 0.05)
Oceania	6365(5233 to 7904)	97.18(79.89 to 120.67)	15,276(12306 to 19152)	109.68(88.36 to 137.51)	139.98(124.08 to 156.49)	-0.16(-0.89 to 0.58)
South Asia	1472930(1161370 to 1875713)	134.71(106.22 to 171.55)	2,592,738(1939892 to 3423035)	140.41(105.05 to 185.37)	76.03(57.67 to 92.96)	-0.08(-0.29 to 0.12)
Southeast Asia	683816(561420 to 840120)	146.9(120.6 to 180.47)	842,851(664405 to 1073641)	120.7(95.15 to 153.75)	23.26(8.75 to 40.16)	-0.64(-0.94 to -0.35)
Southern Latin America	39083(30505 to 51671)	78.9(61.58 to 104.31)	52,988(41771 to 68543)	78.28(61.71 to 101.25)	35.58(28.24 to 44.45)	0(-0.07 to 0.07)
Southern Sub-Saharan Africa	80946(63454 to 102821)	154.42(121.05 to 196.16)	90,513(72703 to 115972)	112.71(90.53 to 144.42)	11.82(7.06 to 17.27)	-1.16(-1.29 to -1.03)
Tropical Latin America	351620(281407 to 449819)	230.49(184.47 to 294.86)	464,479(360507 to 605940)	204.14(158.45 to 266.32)	32.1(22.11 to 42.48)	-0.28(-0.34 to -0.22)
Western Europe	437117(338109 to 564141)	113.71(87.95 to 146.75)	488,120(339787 to 692709)	111.6(77.69 to 158.37)	11.67(-2.14 to 23.81)	-0.07(-0.11 to -0.02)
Western Sub-Saharan Africa	176601(145088 to 218050)	91.43(75.11 to 112.89)	381,261(313341 to 466761)	77.84(63.97 to 95.29)	115.89(108.02 to 124.09)	-0.61(-0.74 to -0.48)

**Note:** Data in parentheses are 95% uncertainty intervals for cases and rates, and 95% confidence intervals for EAPC.



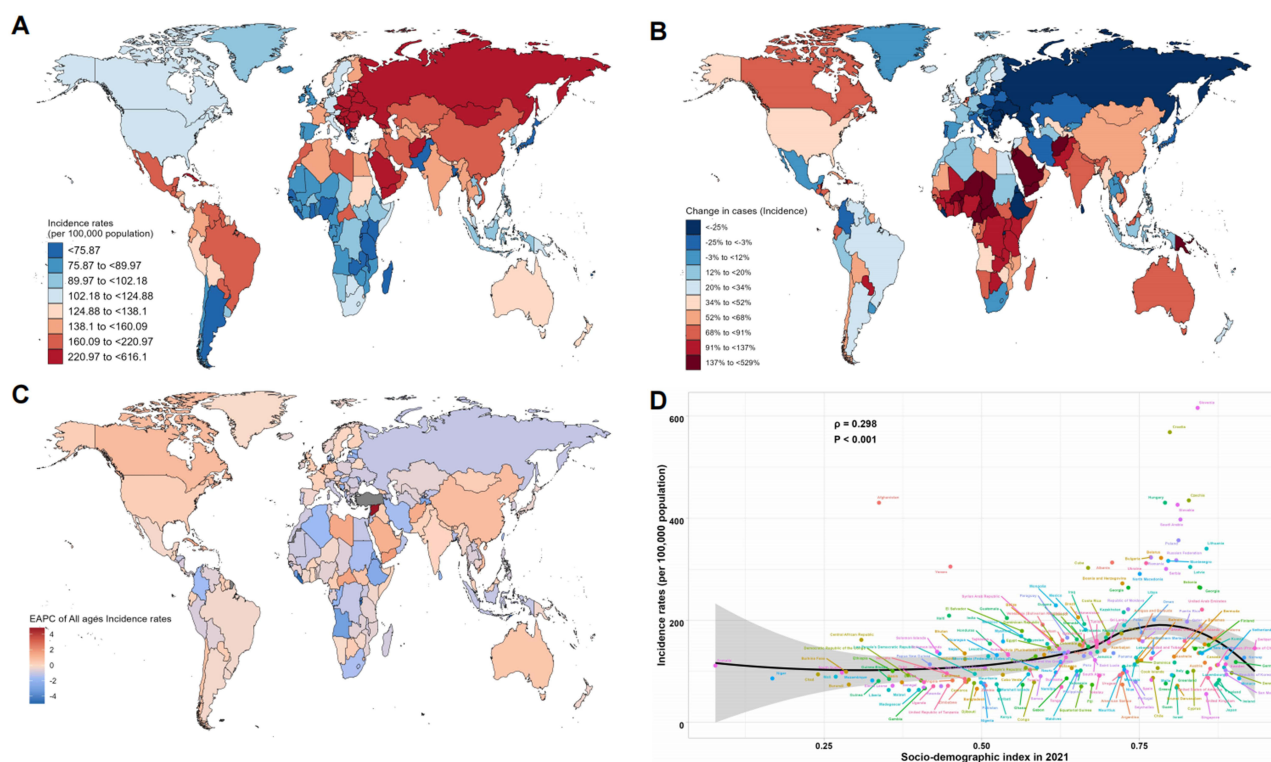
**Figure 2** Regional epidemiological trends of femoral fractures (excluding femoral neck fractures). **(A)** New cases from 1990 to 2021 by SDI regions. **(B)** Incidence rates from 1990 to 2021 by SDI regions. **(C)** Incidence rates in 2021 for global, five SDI regions, and 21 GBD regions by sex. **(D)** Correlation between incidence rates and SDI values from 1990 to 2021.

Overall, from 1990 to 2021, the burden of femoral fracture incidence declined in most regions, suggesting improvements in healthcare access and preventive measures. Notably, Central Sub-Saharan Africa, Eastern Sub-Saharan Africa, and Southern Sub-Saharan Africa experienced the most significant improvements, with EAPCs of  $-1.58$ ,  $-1.85$ , and  $-1.16$ , respectively (Table 1). In contrast, there is growing concern that the incidence burden in the Caribbean and East Asia continues to rise, with EAPCs of  $0.76$  and  $0.75$ , respectively (Table 1). This contrasting trend underscores the need for targeted interventions in regions where incidence rates are increasing. Through the analysis of the correlation between SDI and incidence rates, we observed that the relationship at the regional level was not particularly strong ( $\rho=0.199$ ,  $p<0.001$ ) (Figure 2D). This contrasting trend not only emphasizes the need for targeted interventions but also sets the stage for a more detailed analysis at the country level.

## National-Level Distribution Characteristics of Femoral Fractures

In 2021, the countries with the highest incidence rates of femoral fractures were Slovenia, Croatia, and Czechia, reporting remarkable rates of  $616.1$ ,  $568.51$ , and  $434.77$  per  $100,000$ , respectively (Figure 3A and Supplementary Table S1). These figures stand in stark contrast to the lowest rates observed in Malawi, Kiribati, and Liberia, which were only  $62.86$ ,  $62.89$ , and  $63.12$  per  $100,000$ —nearly ten times lower (Figure 3A and Supplementary Table S1). Comparing the data from 1990 to 2021 reveals that Afghanistan, Qatar, and the United Arab Emirates experienced dramatic increases in incidence rates, with growth rates of  $528.7\%$ ,  $422.8\%$ , and  $405.1\%$ , respectively (Figure 3B). Conversely, Eritrea, Liberia, and Latvia saw significant declines in their incidence numbers, with decreases of  $72.6\%$ ,  $62.1\%$ , and  $56.2\%$  (Figure 3B).

Moreover, the most notable improvements in the burden of femoral fracture incidence were observed in Burundi, Liberia, and Timor-Leste, which reported EAPCs of  $-4.96$ ,  $-4.83$ , and  $-4.9$ , respectively (Figure 3C and Supplementary Table S1). An analysis of the correlation between SDI and femoral fracture incidence rates across countries revealed a weak positive relationship at the national level ( $\rho=0.298$ ,  $p<0.001$ ) (Figure 3D). This finding suggests that while



**Figure 3** Epidemiological trends of femoral fractures (excluding femoral neck fractures) in 204 Countries. **(A)** Incidence rates by country in 2021. **(B)** Percentage change in new cases by country between 1990 and 2021. **(C)** EAPC values by country from 1990 to 2021. **(D)** Correlation between incidence rates and SDI values in 2021.

socioeconomic development may be linked to incidence rates, additional factors likely play a significant role in shaping these trends.

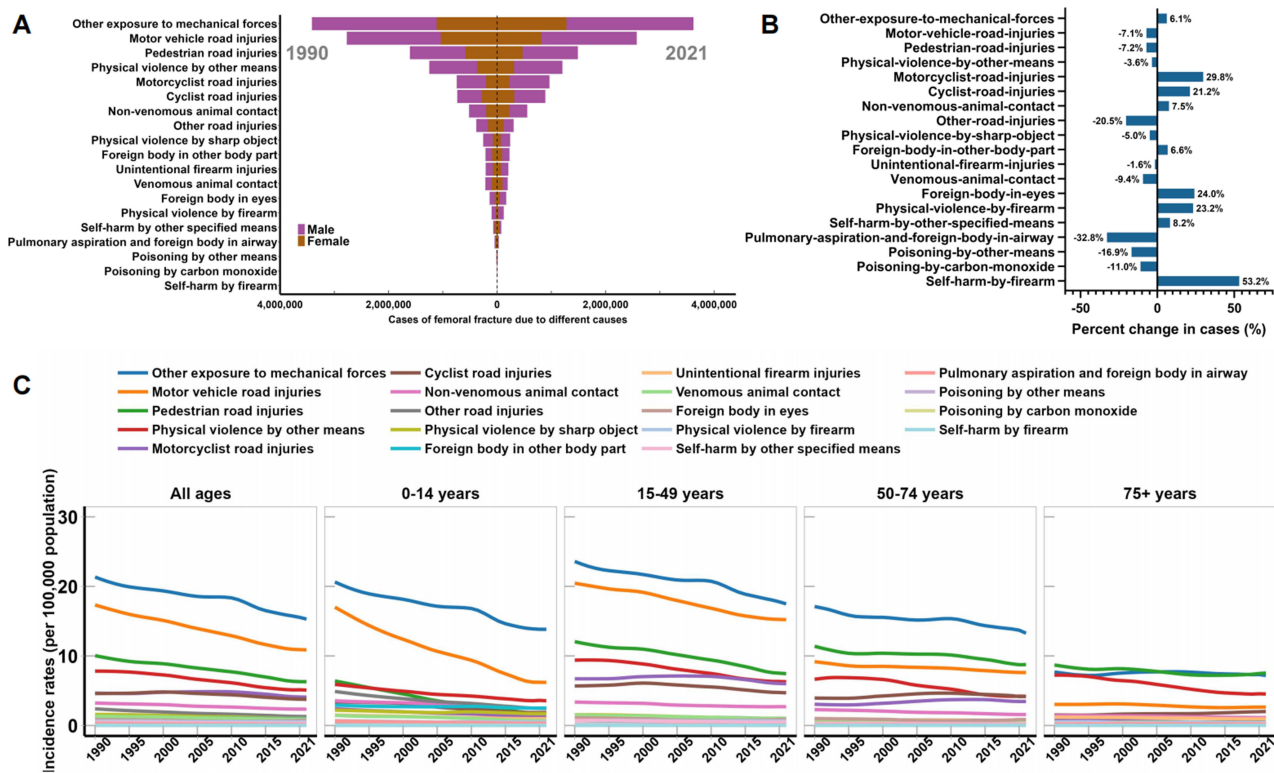
## Primary Causes of Femoral Fractures

To further explore the global landscape of femoral fractures, we identified the primary causes contributing to these injuries. The top five causes were Other exposure to mechanical forces, Motor vehicle road injuries, Pedestrian road injuries, Physical violence by other means, and Motorcyclist road injuries (Figure 4A). In 2021, these resulted in 1,207,375, 858,130, 496,797, 401,689, and 322,238 cases, respectively, reflecting percentage changes from 1990 of 6.07%, -7.14%, 7.22%, 3.64%, and 29.8% (Figure 4A, B and Table 2). In the context of gender differences in femoral fractures, the incidence rates for Other exposure to mechanical forces were 147.29 per 100,000 for males and 48.49 per 100,000 for females (Supplementary Figure S2). Notably, all 19 causes of femoral fractures showed a declining incidence rate from 1990 to 2021. The most significant improvements were observed in five causes: Pulmonary aspiration and foreign body in airway, Other road injuries, Poisoning by other means, Venomous animal contact, and Physical violence by other means, with EAPC values of -2.41, -1.96, -1.75, -1.73, and -1.58, respectively (Table 2). These causes reflect the complexities surrounding femoral fractures, emphasizing the need for targeted prevention strategies.

In terms of age stratification, the highest incidence rates for the age groups 0–14 years, 15–49 years, and 50–74 years were attributed to Other exposure to mechanical forces (Figure 4C). Conversely, individuals aged 75 and older were more prone to femoral fractures due to Pedestrian road injuries (Figure 4C). This highlights the differing risks faced by various age groups and suggests that prevention efforts should be tailored accordingly.

## Regional Variations in Primary Causes of Femoral Fractures

Building on our previous analysis of the global burden of femoral fractures, we now turn to the specific causes contributing to these injuries across different SDI regions. In the High-middle SDI region, the incidence rate of femoral fractures attributed to Other exposure to mechanical forces was notably higher, reaching 23.49 per 100,000 in 2021.



**Figure 4** Distribution of major causes of femoral fractures (excluding femoral neck fractures). **(A)** New cases by cause for global males and females in 1990 and 2021. **(B)** Percentage change in new cases by cause between 1990 and 2021. **(C)** Incidence rates by cause for different age groups globally from 1990 to 2021.

However, this figure reflects a significant decline from 36.89 per 100,000 in 1990, with an EAPC of  $-1.35$  (Figure 5A and Supplementary Table S2). In 2021, the incidence rates for this cause in the High SDI, High-middle SDI, Middle SDI, and Low SDI regions were 13.5, 15.8, 12.08, and 11.81 per 100,000, respectively (Supplementary Table S2). As the second leading cause, Motor vehicle road injuries exhibited relatively stable rates across all SDI categories, fluctuating between 10 and 12 per 100,000 (Figure 5A and Supplementary Table S2). Furthermore, distinct differences in the distribution of various causes leading to femoral fractures were observed across regions; for instance, in Central Europe, Other exposure to mechanical forces accounted for 70.9% of femoral fractures in 2021, followed closely by Australasia at 58.8% (Figure 5B). This variation underscores the need for region-specific prevention strategies tailored to the prevalent causes of injury.

## Discussion

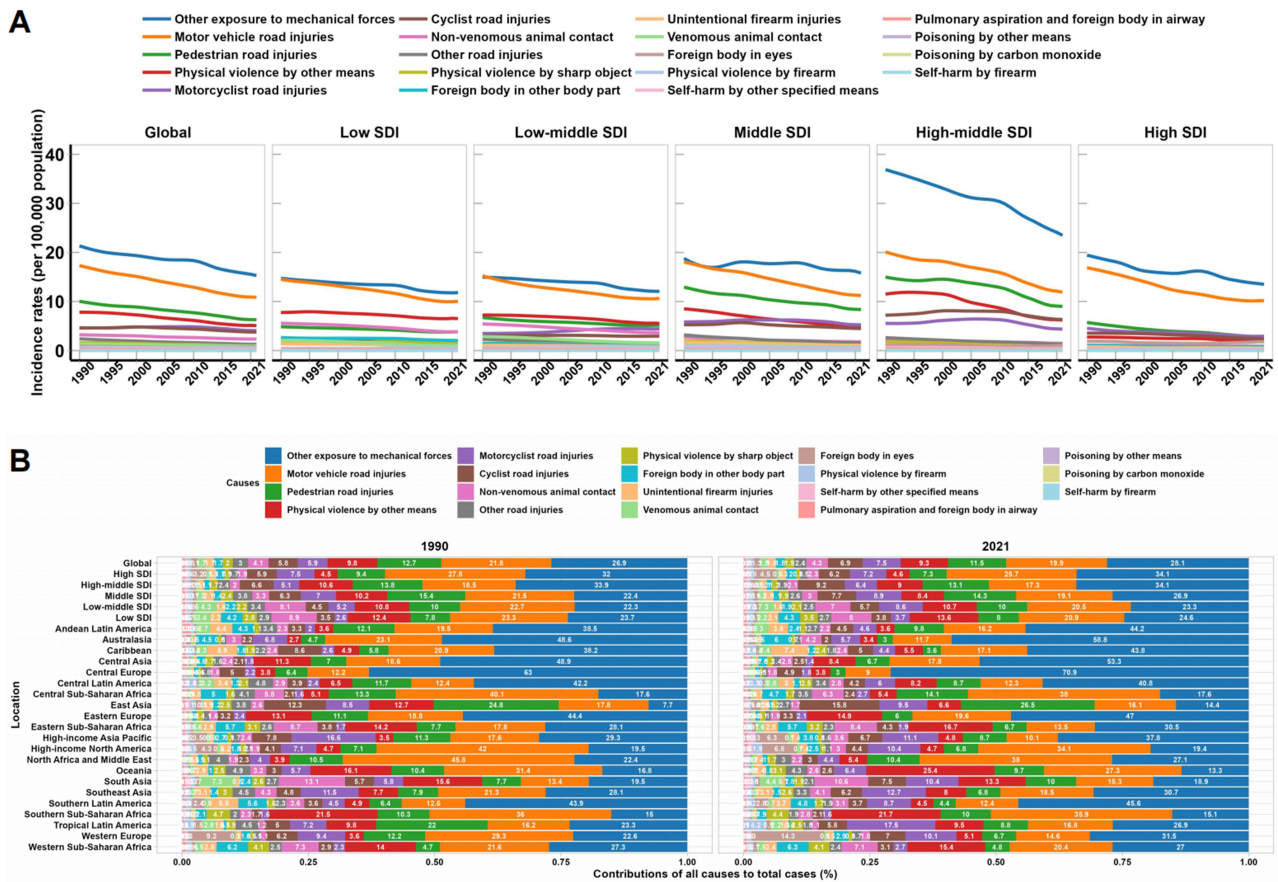
This study highlights significant global trends in the incidence and primary causes of femoral fractures over the past 32 years. While the overall incidence rate decreased from 160.49 per 100,000 in 1990 to 146.57 per 100,000 in 2021, the burden of femoral fractures remains notably higher among males than females. In 2021, the incidence rates were 155.53 per 100,000 for males and 137.55 per 100,000 for females. This gender disparity aligns with findings from other studies, which suggest that men are more frequently engaged in high-risk activities, such as intense physical labor or contact sports, increasing their likelihood of sustaining femoral fractures.<sup>19,20</sup> Targeted prevention strategies that specifically address male-dominated risk behaviors could be beneficial in reducing incidence rates in this demographic.

The marked increase in femoral fractures among individuals aged 75 and older emphasizes the implications of an aging population, where falls are a predominant risk factor.<sup>21</sup> The increase of 232.67% in this age group signals a growing public health challenge. Studies from countries with aging populations, such as Japan and Italy, have also reported similar trends, linking increased fall rates to frailty and comorbid conditions. Implementing effective preventive measures, such as fall prevention programs, enhancing home safety, and improving balance training, could significantly

**Table 2** The Incidence and Trends of All Different Potential Causes of Femoral Fractures (Excluding Femoral Neck Fractures) Globally from 1990 to 2021

Causes	1990		2021		Cases_Change (%)	EAPC
	Cases, n	Incidence Rates, Per 100,000	Cases, n	Incidence Rates, Per 100,000		
Cyclist road injuries	245276(123914 to 423372)	4.6(2.32 to 7.94)	297,159(154159 to 506074)	3.77(1.95 to 6.41)	21.15(10.6 to 32.47)	-0.72(-0.87 to -0.57)
Foreign body in eyes	45597(13417 to 115471)	0.85(0.25 to 2.16)	56,551(16508 to 139950)	0.72(0.21 to 1.77)	24.02(11.98 to 36.24)	-0.99(-1.31 to -0.68)
Foreign body in other body part	71536(25680 to 167942)	1.34(0.48 to 3.15)	76,282(28189 to 178460)	0.97(0.36 to 2.26)	6.63(2.95 to 12.67)	-1.03(-1.07 to -0.99)
Motor vehicle road injuries	924083(571978 to 1368068)	17.33(10.72 to 25.65)	858,130(542900 to 1248353)	10.87(6.88 to 15.82)	-7.14(-13.35 to -0.96)	-1.56(-1.6 to -1.52)
Motorcyclist road injuries	248254(147011 to 382812)	4.65(2.76 to 7.18)	322,238(198445 to 491582)	4.08(2.51 to 6.23)	29.8(20.26 to 40.01)	-0.29(-0.46 to -0.12)
Non-venomous animal contact	172236(72226 to 325622)	3.23(1.35 to 6.11)	185,086(77752 to 349234)	2.35(0.99 to 4.43)	7.46(1.75 to 14.21)	-1.11(-1.15 to -1.07)
Other exposure to mechanical forces	1138240(573678 to 2087164)	21.34(10.76 to 39.13)	1,207,375(594741 to 2262816)	15.3(7.54 to 28.67)	6.07(0.35 to 11.87)	-0.96(-1.04 to -0.88)
Other road injuries	127745(60459 to 240750)	2.4(1.13 to 4.51)	101,620(50962 to 185238)	1.29(0.65 to 2.35)	-20.45(-27.89 to -10.82)	-1.96(-1.99 to -1.93)
Pedestrian road injuries	535464(330610 to 840356)	10.04(6.2 to 15.76)	496,797(301615 to 792048)	6.3(3.82 to 10.04)	-7.22(-15.67 to 0.9)	-1.48(-1.56 to -1.41)
Physical violence by firearm	33410(15266 to 67243)	0.63(0.29 to 1.26)	41,171(19223 to 81681)	0.52(0.24 to 1.04)	23.23(12.5 to 34.83)	-0.7(-0.79 to -0.61)
Physical violence by other means	416855(209866 to 752554)	7.82(3.93 to 14.11)	401,689(204871 to 737254)	5.09(2.6 to 9.34)	-3.64(-7.89 to 1.72)	-1.58(-1.67 to -1.5)
Physical violence by sharp object	85072(30870 to 185916)	1.6(0.58 to 3.49)	80,799(30211 to 171034)	1.02(0.38 to 2.17)	-5.02(-11.07 to 2.94)	-1.55(-1.6 to -1.49)
Poisoning by carbon monoxide	1510(634 to 3249)	0.03(0.01 to 0.06)	1344(597 to 2799)	0.02(0.01 to 0.04)	-10.99(-16.26 to -2.53)	-1.41(-1.62 to -1.2)
Poisoning by other means	4666(2142 to 9621)	0.09(0.04 to 0.18)	3878(1774 to 7815)	0.05(0.02 to 0.1)	-16.88(-20.08 to -13.13)	-1.75(-1.83 to -1.67)
Pulmonary aspiration and foreign body in airway	15895(7536 to 31635)	0.3(0.14 to 0.59)	10,680(5133 to 21115)	0.14(0.07 to 0.27)	-32.81(-37.83 to -26.97)	-2.41(-2.53 to -2.29)
Self-harm by firearm	477(131 to 1342)	0.01(0 to 0.03)	730(207 to 2028)	0.01(0 to 0.03)	53.22(34.42 to 75.29)	-0.21(-0.34 to -0.08)
Self-harm by other specified means	23644(10194 to 45511)	0.44(0.19 to 0.85)	25,573(11268 to 48674)	0.32(0.14 to 0.62)	8.16(0.78 to 16.27)	-1.46(-1.57 to -1.35)
Unintentional firearm injuries	70327(24136 to 158760)	1.32(0.45 to 2.98)	69,187(24383 to 153342)	0.88(0.31 to 1.94)	-1.62(-9.54 to 8.11)	-1.34(-1.38 to -1.31)
Venomous animal contact	72356(22076 to 167899)	1.36(0.41 to 3.15)	65,545(18598 to 156372)	0.83(0.24 to 1.98)	-9.41(-19.8 to -1.16)	-1.73(-1.83 to -1.63)

**Note:** Data in parentheses are 95% uncertainty intervals for cases and rates, and 95% confidence intervals for EAPC.



**Figure 5** Regional differences in the distribution of major causes of femoral fractures (excluding femoral neck fractures). **(A)** Incidence rates by cause globally and across five SDI regions from 1990 to 2021. **(B)** Cumulative contribution of new cases by cause in 1990 and 2021 for global, five SDI regions, and 21 GBD regions.

mitigate fracture risk among older adults.<sup>22,23</sup> Community-based initiatives focused on educating healthcare providers and caregivers about fall risks could further enhance awareness and promote safer living environments.<sup>24</sup>

Geographical variations in incidence rates across different SDI regions highlight the importance of considering regional contexts in public health policy.<sup>25</sup> The high rates of femoral fractures attributed to “Other exposure to mechanical forces” in high and middle-high SDI regions, reaching 23.49 per 100,000 in 2021, indicate the need for improved safety regulations and practices in occupational and recreational settings. Previous research has demonstrated that countries with stringent occupational safety regulations report lower injury rates.<sup>26</sup> Tailoring prevention strategies to address the specific needs and characteristics of these regions—such as enhancing workplace safety standards and promoting awareness of mechanical risks—could lead to substantial reductions in femoral fracture rates.

A recent study has also examined the global epidemiology of femoral fractures, covering trends in incidence, prevalence, and disability.<sup>27</sup> For instance, it reported a global decline in the age-standardized incidence rate with notable regional variations, particularly in East Asia and sub-Saharan Africa.<sup>27</sup> However, while this study primarily focused on incidence trends and disability outcomes, our research distinguishes itself by placing a stronger emphasis on the primary causes of femoral fractures, such as mechanical forces, motor vehicle accidents, and pedestrian injuries. By highlighting these causal factors, we provide critical insights into regional disparities and offer a foundation for targeted preventive strategies, which further underscores the relevance and novelty of our findings in global epidemiology. While the overall incidence of femoral fractures has declined, certain causes, particularly motor vehicle road injuries, remain a significant concern.<sup>28</sup> The stable incidence rates of 10 to 12 per 100,000 across various SDI categories emphasize the importance of continued efforts to enhance traffic safety. Comparative studies

have shown that countries with robust traffic laws and public awareness campaigns, such as Sweden, report significantly lower rates of road-related injuries.<sup>29</sup> Strengthening legislation on road safety, increasing public awareness campaigns, and improving road infrastructure are critical components in addressing this persistent issue.<sup>29</sup>

This study has certain limitations that should be acknowledged. The reliance on existing datasets may introduce biases, particularly regarding the completeness and accuracy of reported cases across different regions.<sup>13</sup> Variations in healthcare access, reporting practices, and diagnostic criteria can affect the comparability of data.<sup>14</sup> Additionally, the study does not account for potential confounding factors such as socioeconomic status, environmental influences, and healthcare system differences that may impact incidence rates and outcomes. Future research should aim to incorporate more comprehensive data sources and methodologies to address these limitations and provide a clearer understanding of the trends in femoral fractures.

In conclusion, this study provides valuable insights into the trends and causes of femoral fractures (excluding femoral neck fractures) on a global scale. Future research should focus on specific populations and regions to develop more precise intervention strategies. Understanding the unique challenges faced by different groups will enable public health initiatives to be more effectively directed, ultimately reducing the global burden of femoral fractures. Continued surveillance and analysis of trends in femoral fracture incidence will be essential for evaluating the impact of implemented prevention measures and for adjusting strategies as necessary to meet emerging challenges.

## Data Sharing Statement

The data are available from the Global Burden of Disease Results Tool of the Global Health Data Exchange (<http://ghdx.healthdata.org/>), and replication details are provided in the [supplementary file](#).

## Ethical Approval

This study was approved by the Ethics Committee of Huangyan Hospital of Traditional Chinese Medicine in line with the Declaration of Helsinki (approval date: September 1, 2024). As a result of the secondary data analysis in this study, the review board waived informed consent. Additionally, this article does not contain any personal information about patients. All authors are in agreement with the manuscript.

## Consent for Publication

We confirm that all participants have provided explicit consent for the publication of their data, and all necessary institutional approvals have been obtained.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

The authors declare no conflicts of interest in this work.

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