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The national and subnational burden of falls and its attributable risk factors among older adults in Iran from 1990 to 2021: findings from the global burden of disease study

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Abstract

Background Falls among older adults (individuals aged 60 and above) are a substantial health issue worldwide. This study aimed to analyze the burden of falls and its attributable risk factors among older adults at the national and subnational levels in Iran over 32 years.

Methods Using the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021 data, we estimated the incidence, prevalence, death, and disability-adjusted life-years (DALYs) of falls and its attributable risk factors among older adults by sex, age groups, and socio-demographic index (SDI) in Iran and its provinces. We reported the estimates with their 95% uncertainty intervals (UIs). Rates were reported per 100,000 population.

Results In 2021 in Iran, the incidence rate of falls among older adults was 1674.0 (95% UI: 1454.9-1897.3), the prevalence rate was 11302.5 (10504.7-12095.7), the death rate was 16.9 (12.9–21.0), and the DALYs rate was 736.3 (647.6-825.4). In 2021, at the subnational level, Qazvin had the highest incidence, death, and DALYs rates for falls with values at 2329.5 (2008.8-2652.1), 24.2 (19.5–29.0), and 965.9 (856.2-1074.6), respectively, while Kohgiluyeh and Boyer-Ahmad had the highest falls prevalence rate at 16043.1 (14918.4-17149.0). In 2021, males had higher prevalence, death, and DALYs rates of falls compared to females, while females had a higher incidence rate. Among the age groups, the 90–94 age group had the highest rates of incidence, prevalence, death, and DALYs from falls. Low bone mineral density was the primary risk factor attributable to the burden of falls. There were significant positive associations between SDI and both the incidence and prevalence rates of falls. Conversely, a significant inverse association was found between SDI and the death rate.

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Conclusions From 1990 to 2021, the incidence rate of falls has increased significantly among older adults in Iran, necessitating urgent interventions. Implementing nationwide, cost-effective strategies such as exercise programs to improve strength and balance, home hazard modifications, medication reviews to reduce fall-related risks, and routine screening programs for osteoporosis and fall risk assessment can help protect and support older people, minimizing their risk of falls.

Keywords Older adults, Accidental falls, Iran, Global burden of diseases, Risk factors

Introduction

Falls among older individuals are a significant concern due to their adverse impact on their independence. Falls are common among the older population and often result from impairments in various areas, undermining their ability to cope with challenges [1]. The incidence of falls increases with age and is influenced by the individual's living conditions [2–6]. Approximately 50% of older individuals residing in long-term care facilities experience falls annually, with nearly 60% of prior fallers at risk of recurrent falls [2–4]. Fall-related injuries result in substantial morbidity, contributing to a decline in functional status, an increased likelihood of nursing home admission, and higher use of medical services [7–10]. Hospital admissions due to fall-related hip fractures or other injuries lead to poorer disability outcomes including prolonged disability in basic, instrumental, and mobility activities, increased dependency, reduced likelihood of functional recovery, and a significantly higher probability of long-term nursing home admission compared to hospitalizations for other conditions [11]. Nearly 95% of hip fractures among older individuals are caused by falls [12].

The incidence of fatal falls is relatively lower than that of non-fatal falls. In 2021, there were 38,742 (78 per 100,000) unintentional fall-related deaths among older adults in the United States [13]. Falls rank as the second leading cause of unintentional injury deaths globally, following road traffic injuries as the leading cause, with an estimated 684,000 fall-related deaths occurring annually, mainly in low- and middle-income countries [14, 15]. Approximately 37.3 million severe falls necessitating medical attention occur each year worldwide, resulting in over 17 million disability-adjusted life-years (DALYs) [15]. It is worth mentioning that the estimated economic burden of fall-related injuries for individuals over 65 in the United States was USD 50 billion in 2015, a figure expected to increase as the older adult population grows [16].

Iran is undergoing a significant demographic transition characterized by a decline in fertility and mortality rates, leading to a rapid aging of its population. Projections indicate that the proportion of individuals aged 60 and above is set to increase from approximately 8% in 2015 to nearly 31% in 2050, marking a substantial fourfold increase [17]. This demographic shift underscores the pressing need to comprehensively examine the epidemiology and impact of falls among older adults in Iran. Understanding the burden of falls and their associated challenges is crucial for developing and implementing effective intervention strategies to mitigate their burden on the healthcare system.

Limited data on falls in Iran is available. Although several studies have investigated the incidence, prevalence, and mortality of falls and the associated factors among older adults in Iran, a comprehensive understanding of the burden of falls still needs to be provided [18–23]. This investigation aimed to evaluate the epidemiology and burden of falls among individuals aged 60 and above in Iran and its provinces, stratified by sex and age, using the Global Burden of Diseases, Injuries, and Risk Factors Study (GBD) 2021 data.

Methods

Overview

This study utilized data from the GBD 2021 to assess the burden of falls and its attributable risk factors among individuals aged 60 and older in Iran and its 31 provinces from 1990 to 2021. The GBD 2021 provides comprehensive estimates of incidence, prevalence, deaths, years lived with disability (YLDs), years of life lost (YLLs), and DALYs for 288 causes of death by age-sex-location-year and 88 risk factors in 204 countries and territories and 811 subnational locations for each year from 1990 until 2021. The detailed methodology of the GBD 2021 has been described elsewhere [24–26]. This study complies with the Guidelines for Accurate and Transparent Health Estimates Reporting (GATHER) statement [27].

Case definition and data source

This study defined older adults as individuals aged 60 and older [28, 29]. In the hierarchy of causes, the GBD classifies falls as level 3, following injuries, and unintentional injuries, which are classified as levels 1 and 2, respectively [30]. Falls include death or disability resulting from a sudden movement downward due to slipping, tripping, or other unintentional movement that results in a person coming to rest at a lower level or against an object [30]. Falls were defined according to the International Classification of Diseases (ICD) codes specific to falls (ICD-9: E880-E886.99, E888-E888.9, E929.3; ICD-10: W00-W19.9) [24, 30]. The socio-demographic index (SDI) is a comprehensive measure of development status

strongly associated with health outcomes. It is the geometric mean of three 0 to 1 indices comprising total fertility rate under the age of 25, mean education for people ages 15 and older, and lag distributed income per capita. It scores from 0 (minimum level of development) to 1 (maximum level of development) and is categorized into five quintiles: low, low-middle, middle, high-middle, and high [31]. The GBD 2021 encompasses many data input sources, including vital registration, verbal autopsy, surveys, censuses, surveillance systems, cancer and disease-specific registries, and health service contact data. These data are obtained to estimate mortality, causes of death and illness, and risk factors. The GBD 2021 data input sources are accessible via The Sources Tool [32].

Modeling strategy

The Cause of Death Ensemble model (CODEm) was used to estimate mortality attributable to falls. CODEm is a modeling tool developed specifically for GBD that assesses the out-of-sample predictive validity of different statistical models and covariate permutations and then combines the results from those assessments to produce cause-specific estimates of the mortality burden [24]. The incidence of falls represents the number of new fall events, whereas the prevalence accounts for both previous and new fall cases in the population [26]. YLLs were calculated by multiplying the deaths by the standard life expectancy at each age [24]. YLDs were estimated by multiplying the prevalence of falls by the disability weight associated with falls [26]. DALYs were then computed as the sum of YLLs and YLDs [26].

Risk factors

We investigated the following risk factors for falls: low bone mineral density (LBMD), occupational injuries, smoking, and alcohol use. LBMD was determined using estimates derived from dual-energy X-ray absorptiometry (DXA) measurements, epidemiological studies, and meta-analyses compiled in the GBD. The study assesses LBMD burden by quantifying the age-specific prevalence of osteoporosis and osteopenia and their association with fall-related fractures. Occupational injuries were defined as work-related injuries among the working-age population, based on fatal injury rates in specified economic activities. These were quantified based on exposure data from occupational safety databases, surveys, and epidemiological studies linking work-related injuries to falls. These were quantified based on exposure data from occupational safety databases, surveys, and epidemiological studies linking work-related injuries to falls. Smoking was categorized into current and former smoking, with exposure measured in pack-years. Alcohol use was quantified using grams of alcohol consumed by current drinkers, per day, over 12 months. Data on the impact of these risk factors were obtained from the GBD 2021, which quantifies risk factor contributions using Comparative Risk Assessment (CRA) methods. This involves calculating population-attributable fractions (PAFs) by integrating exposure prevalence, relative risks from epidemiological studies, and theoretical minimum risk exposure levels (TMRELs) to estimate the proportion of falls burden attributable to each risk factor. Further details on the risk factors are provided elsewhere [25].

Statistical analysis

To describe the time trend of the burden attributable to falls, we calculated numbers, rates, and their estimated percentage changes from 1990 to 2021 for incidence, prevalence, deaths, DALYs, YLDs, and YLLs. Age was categorized into the following groups: 60–64, 65–69, 70–74, 75–79, 80–84, 85–89, 90–94. All estimates were reported with 95% uncertainty intervals (UIs), derived from the 2.5th and 97.5th percentiles of 500 draw samples generated through the modeling process [26]. Considering that the GBD estimations did not provide specific data for the entire older adult population (aged 60 and older), we calculated metrics for this age group using data from the 60–64, 65–69, and 70 + age groups provided by GBD. We drew 1,000 samples from the posterior distributions of these age groups and summed them to obtain estimates for the older adult age group, along with their 95% UIs. All statistical analyses and data visualization were conducted using Python version 3.8 [33].

Results

National epidemiology of falls

In Iran, at the national level, the disease burden of falls among older adults has changed from 1990 to 2021 (Table 1). The number of incident cases of falls in both sexes has increased from 43121.4 (95% UI: 35210.17-51009.62) in 1990 to 154130.4 (133699.8-174778.59) in 2021, with a percentage change (PC) of 249.98% (186.17-352.95). The incidence rate of falls has increased by 18.14% (-3.34-51.89), from 1393.45 per 100,000 (1144.22-1646.45) in 1990 to 1673.99 per 100,000 (1454.93-1897.25) in 2021. Additionally, the number of prevalent cases of falls has increased from 355942.98 (329302.56-382014.87) in 1990 to 1040254.69 (970759.33-1109557.61) in 2021, with 189.15% (164.94–223.3) PC. The prevalence rate of falls remained almost constant, with a slight 2.04% decrease (-11.14-9.61), from 11479.69 per 100,000 (10609.61-12355.56) in 1990 to 11302.49 per 100,000 (10504.74-12095.67) in 2021. Moreover, the number of deaths related to falls has increased from 531.35 (429.88–629.7) in 1990 to 1556.25 (1165.07-1945.64) in 2021, with a PC of 190.17% (109.06-297.87). The death rate of falls remained almost stable, with a slight 1.64% decline (-28.95-32.74), from 17.16

Table 1 Number and rate of incidence, prevalence, deaths, disability-adjusted life years (DALYs), years lived with disability (YLDs), and years of life lost (YLLs) attributable to falls in older adult (individuals aged 60 and above) by sex in 1990 and 2021 and overall percentage change over 1990–2021 in Iran

Measure	Metric	Year						% Change (1990 to 2021)		
		1990			2021					
		Both	Female	Male	Both	Female	Male	Both	Female	Male
Incidence	Number	43121.4 (35210.17-51009.62)	21806.95 (18102.0-25466.49)	21335.93 (17048.72-25759.19)	154130.4 (133699.8-174778.59)	86486.1 (74739.59-98429.68)	67656.91 (58703.14-76899.39)	249.98 (186.17–352.95)	288.24 (219.82–397.08)	212.99 (151.27–310.75)
	Rate	1393.45 (1144.22-1646.45)	1509.19 (1254.04-1772.78)	1289.13 (1020.95-1557.39)	1673.99 (1454.93-1897.25)	1853.09 (1610.58-2100.12)	1485.69 (1278.72-1686.78)	18.14 (-3.34–51.89)	21.78 (-0.68–54.07)	12.97 (-9.6–50.87)
Prevalence	Number	355942.98 (329302.56-382014.87)	112843.23 (104392.31-121030.23)	242916.89 (223706.66-262457.41)	1040254.69 (970759.33-1109557.61)	379806.5 (352078.57-407758.5)	661615.02 (614448.2-708403.91)	189.15 (164.94–223.3)	236.76 (203.54–273.98)	171.63 (145.05–203.17)
	Rate	11479.69 (10609.61-12355.56)	7813.93 (7241.64-8389.61)	14692.24 (13501.95-15882.16)	11302.49 (10504.74-12095.67)	8123.82 (7535.86-8740.18)	14567.73 (13481.75-15630.3)	-2.04 (-11.14–9.61)	3.28 (-6.18–15.52)	-1.6 (-11.22–10.81)
Deaths	Number	531.35 (429.88–629.7)	182.2 (143.2–221.0)	350.09 (274.25-424.71)	1556.25 (1165.07-1945.64)	652.52 (498.01-807.43)	902.64 (607.07-1207.77)	190.17 (109.06–297.87)	253.72 (156.08–394.43)	154.0 (64.41–276.93)
	Rate	17.16 (13.95–20.43)	12.6 (9.87–15.33)	21.2 (16.54–25.65)	16.89 (12.85–20.98)	13.97 (10.64–17.25)	19.89 (13.32–26.52)	-1.64 (-28.95–32.74)	9.58 (-20.53–52.98)	-8.74 (-39.84–37.8)
DALYs (Disability-Adjusted Life Years)	Number	26194.9 (23219.85-29138.81)	8656.04 (7637.31-9648.87)	17566.46 (15391.28-19779.36)	67857.18 (59313.91-76124.3)	26465.88 (23371.46-29643.73)	41322.57 (35806.21-46881.02)	156.75 (118.34–206.73)	204.68 (158.27–261.81)	133.78 (95.61–183.22)
	Rate	846.56 (753.73–940.9)	599.19 (529.97-669.07)	1061.24 (931.36-1192.41)	736.26 (647.57-825.41)	567.26 (502.37–633.1)	909.15 (789.26-1028.09)	-13.11 (-26.49–2.44)	-5.78 (-19.69–11.84)	-16.35 (-28.52–2.9)
YLDs (Years Lived with Disability)	Number	16284.97 (13695.31-18844.36)	5730.59 (4897.37-6561.85)	10536.15 (8774.39-12355.93)	44698.64 (38048.26-51255.2)	17511.85 (14738.06-20227.83)	27196.12 (22776.48-31624.69)	172.6 (120.97–244.41)	204.57 (144.46–279.2)	155.52 (103.47–227.48)
	Rate	524.7 (443.59-609.42)	396.89 (340.84-452.97)	639.16 (536.1-746.22)	485.99 (411.46-561.33)	374.95 (319.57-429.72)	598.65 (502.91–691.6)	-7.49 (-26.26–16.25)	-6.62 (-23.16–15.87)	-8.03 (-25.31–18.21)
YLLs (Years of Life Lost)	Number	9952.33 (8414.3-11488.56)	2934.39 (2395.64-3462.69)	7008.7 (5690.32-8309.85)	23082.22 (18548.48-27734.98)	8934.04 (7165.53–10714.0)	14136.42 (10789.88-17547.82)	128.22 (78.52–197.92)	197.05 (130.65–298.7)	98.88 (46.2–172.55)
	Rate	321.14 (271.33-370.87)	202.88 (166.33–238.9)	425.51 (346.4-503.6)	250.71 (201.79-299.17)	191.58 (152.92-230.97)	311.03 (236.88–385.7)	-22.54 (-40.04 - -0.07)	-6.96 (-28.85–23.9)	-28.19 (-46.82 - -1.53)

per 100,000 (13.95–20.43) in 1990 to 16.89 per 100,000 (12.85–20.98) in 2021. Furthermore, the number of DALYs attributed to falls has increased from 26194.9 (23219.85-29138.81) in 1990 to 67857.18 (59313.91-76124.3) in 2021, with 156.75% (118.34-206.73) PC. The DALY rate has decreased by 13.11% (-26.49-2.44), from 846.56 per 100,000 (753.73–940.9) in 1990 to 736.26 per 100,000 (647.57-825.41) in 2021 (Table 1; Fig. 1).

Provincial epidemiology of falls

Figure 2 shows the incidence, prevalence, death, and DALYs rates for falls across provinces of Iran in 2021. In 2021, Qazvin (2329.49 [2008.78-2652.10]) and Sistan and Baluchistan (1004.89 [865.47-1141.40]) experienced the highest and lowest incidence rates for falls, respectively (Fig. 2A). Moreover, Kohgiluyeh and Boyer-Ahmad (16043.07 [14918.37-17148.97]) and Sistan and Baluchistan (8484.88 [7876.65-9068.06]) exhibited the highest and lowest prevalence rates for falls, respectively (Fig. 2B). Furthermore, Qazvin recorded the highest death and DALYs rates attributed to falls, with values at (24.22 [19.50-28.96]) and (965.87 [856.19-1074.60]), respectively (Fig. 2C and D). On the other hand, Khuzestan reported the lowest death and DALYs rates due to falls, with values at (9.72 [4.78–14.77]) and (533.56 [441.20-624.30]), respectively (Fig. 2C and D). The data on the epidemiology and burden metrics of falls among older adults in provinces of Iran in 1990 and 2021 is available from Additional file 1 (see Additional file 1). The provinces mainly located in the West of Iran had the

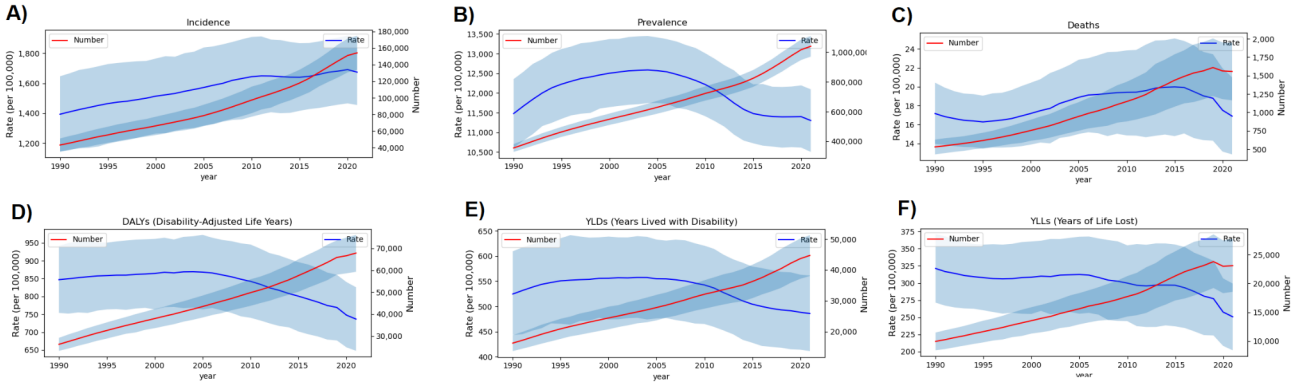

Fig. 1 Time trend of (**A**) incidence, (**B**) prevalence, (**C**) death, (**D**) disability-adjusted life-years (DALYs), (**E**) years lived with disability (YLDs), and (**F**) Years of Life Lost (YLLs) numbers and rates for falls in Iran from 1990 to 2021

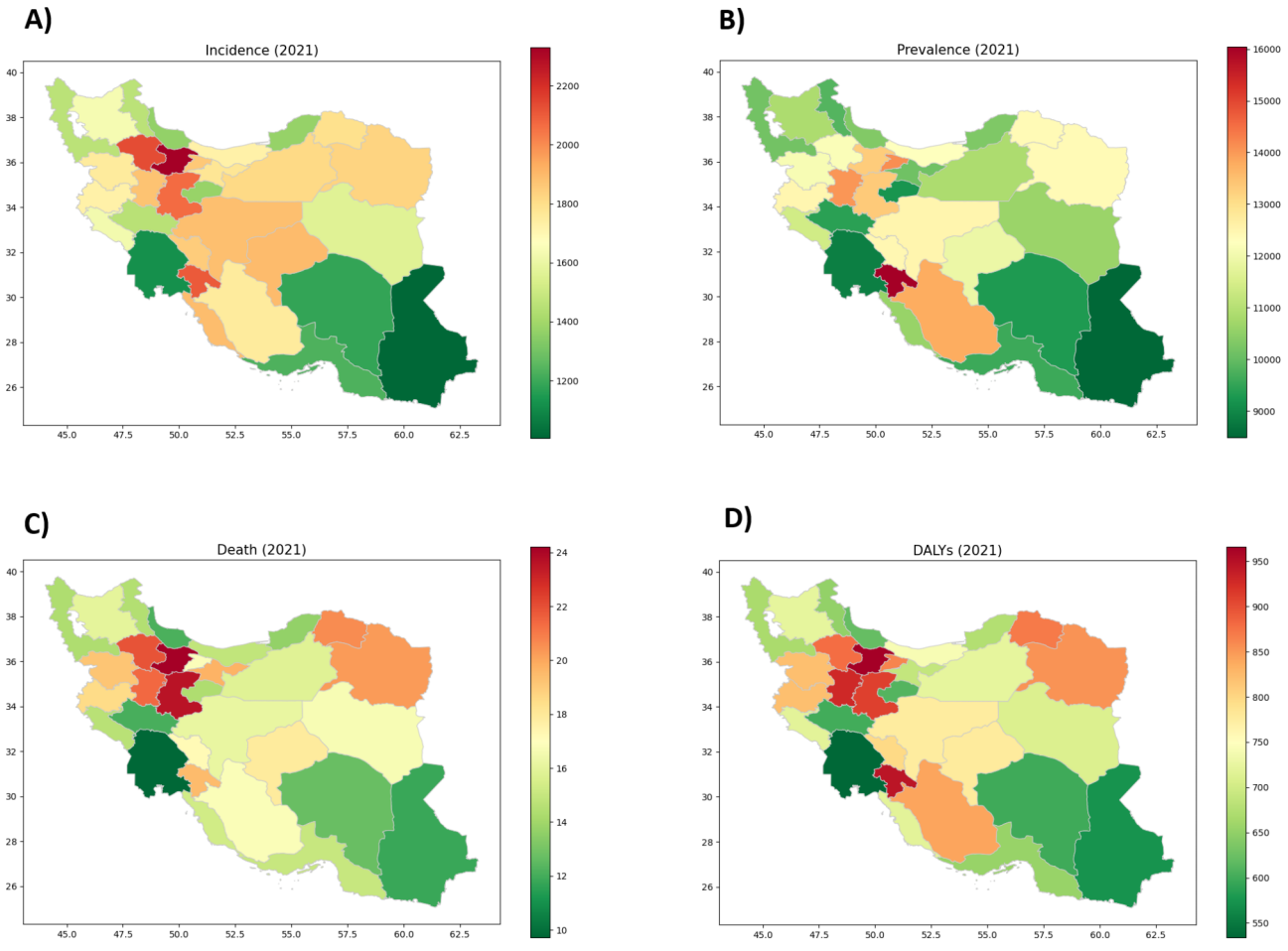

Fig. 2 Geographical distribution of (**A**) incidence, (**B**) prevalence, (**C**) death, and (**D**) disability-adjusted life-years (DALYs) for falls in Iran in 2021

highest burden from falls in the country. Figure 3 shows the differences in fall burden trends between 2000 and 2010, and 2010 and 2021, and how these trends altered over time. Between 2000 and 2010, the death rate of falls in older adults among provinces of Iran was on the rise, while from 2010 to 2021, the trend shifted to a decline (Fig. 3A). Moreover, from 2000 to 2021, the DALYs rate of falls had an overall decrease, with a more pronounced decline observed between 2010 and 2021 (Fig. 3B).

Age and sex patterns of falls burden in Iran

Based on Fig. 4, the national incidence, prevalence, death, and DALY rates of falls in Iran, in both females and males, exhibited an overall increasing trend with age,

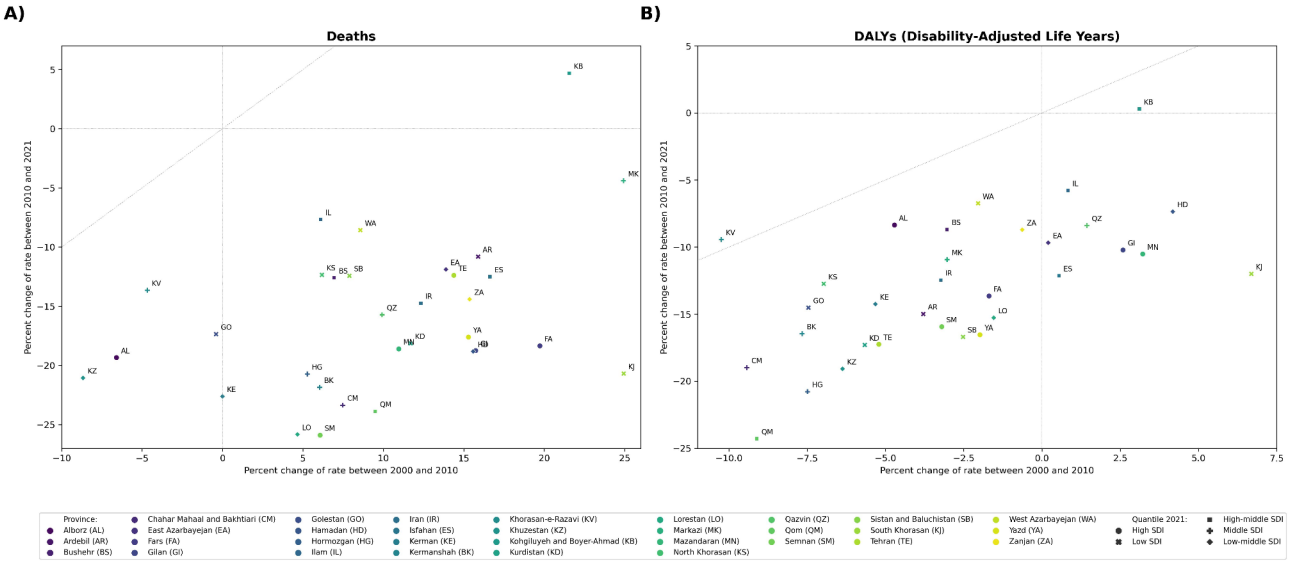

Fig. 3 Percent change of (**A**) death rate and (**B**) disability-adjusted life-years (DALYs) rate among older adults in provinces of Iran between 2000 and 2010, and between 2010 and 2021. Each colored shape represents the percent change of death or DALYs rate for a province and its socio-demographic index (SDI) quintile. The black shapes represent the five SDI quintiles

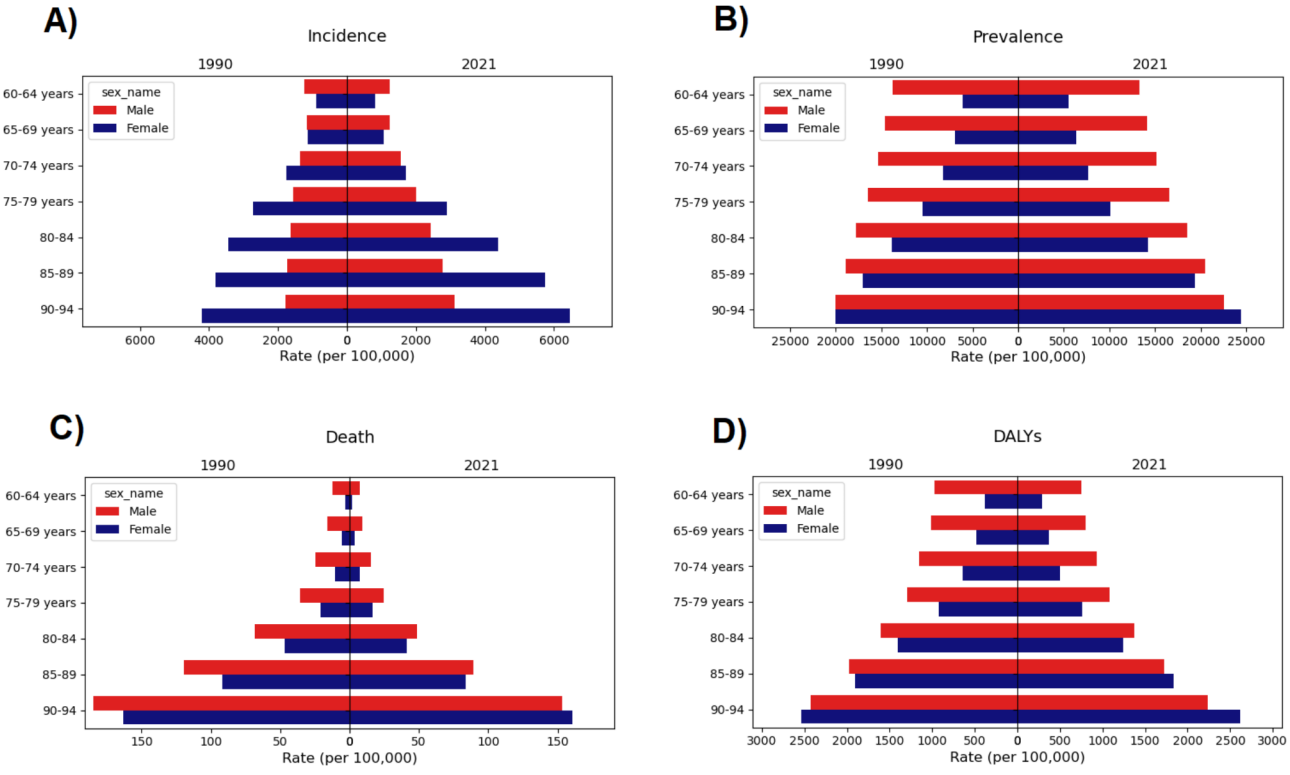

Fig. 4 Rates of (**A**) incidence, (**B**) prevalence, (**C**) death, and (**D**) disability-adjusted life-years (DALYs) for falls by sex and age groups in Iran in 1990 and 2021

peaking at the 90 to 94 age group (Fig. 4). In both 1990 and 2021, males experienced higher rates of prevalence, deaths, and DALYs for falls compared to females, while females had a higher incidence rate than males (Table 1). Notably, from 1990 to 2021, despite the decreasing trend of death rate in males, females had an increasing trend (Table 1).

Regarding incidence rates, from 1990 to 2021, males experienced higher rates in the 60–64 and 65–69 age groups than females. However, females had higher rates

in age groups 70–74 and older, and the gap between males and females constantly widened during this period (Fig. 4). As for death rates, from 1990 to 2021, males exhibited higher rates in all age groups than females. Nevertheless, in 2021, females had higher rates than males in the 90–94 age group, and the gap between males and females shrank (Fig. 4). Concerning DALYs rates, in 1990, males had higher rates in all age groups except the 90–94 age group than females, while in 2021, males had lower rates in the 85–89 age group as well as the 90–94 age group compared to females (Fig. 4).

The attributable burden of falls to risk factors

In Iran, in 2021, as well as in 1990, the burden of falls was attributable to four main risk factors, including LBMD, occupational injuries, smoking, and alcohol use (Fig. 5). Additionally, the risk factors that contributed the most to the deaths due to falls were LBMD, followed by occupational injuries and smoking (Fig. 5). Among the risk factors, LBMD contributed the most to DALYs and deaths from falls in Iran and all its provinces (Figs. 5 and 6). As indicated in Fig. 6, with aging, the proportion of DALYs and deaths attributable to LBMD increased significantly,

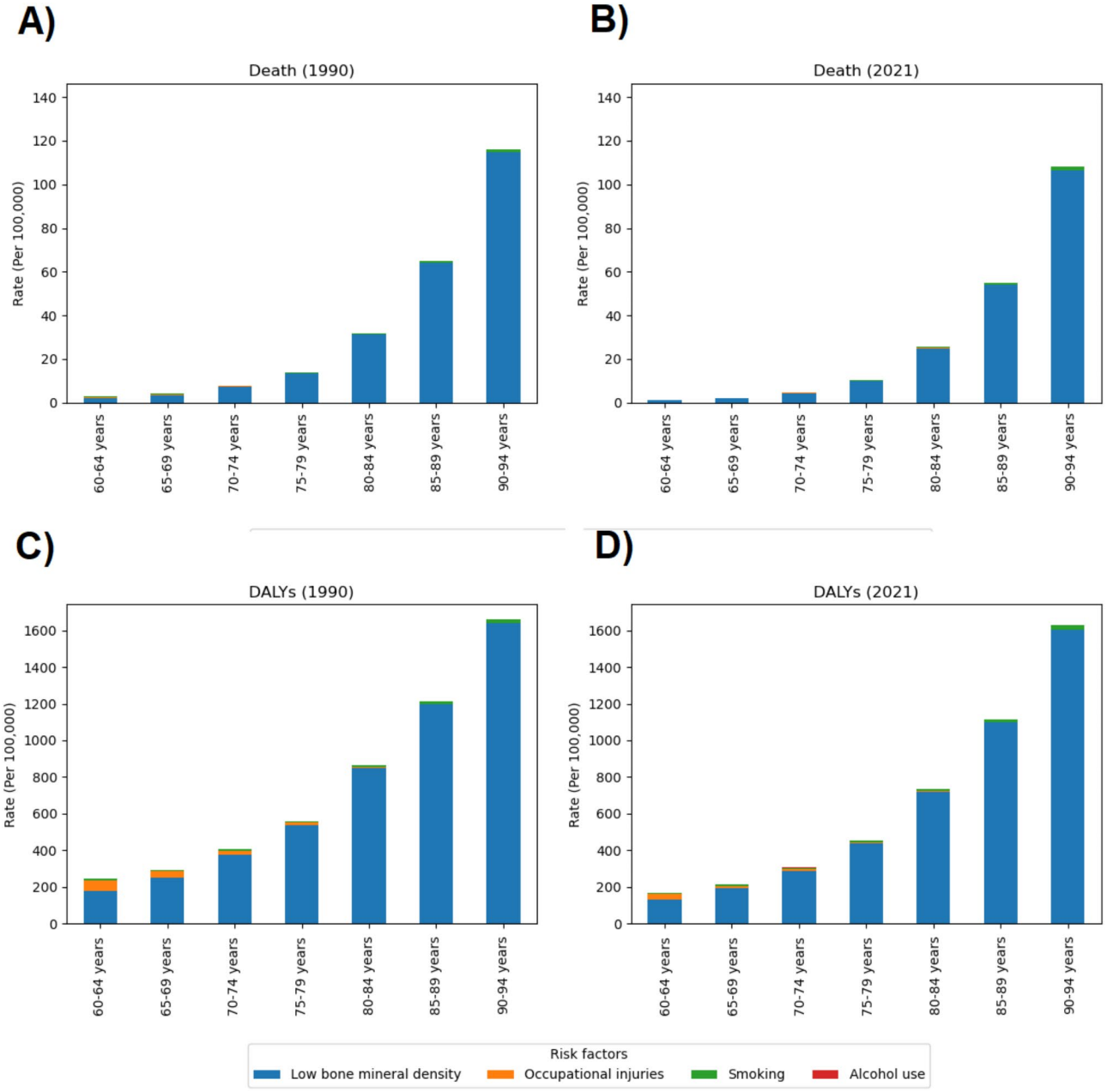

Fig. 5 Rates of (**A**, **B**) death, and (**C**, **D**) disability-adjusted life-years (DALYs) for falls by age groups and risk factors in Iran in 1990 and 2021

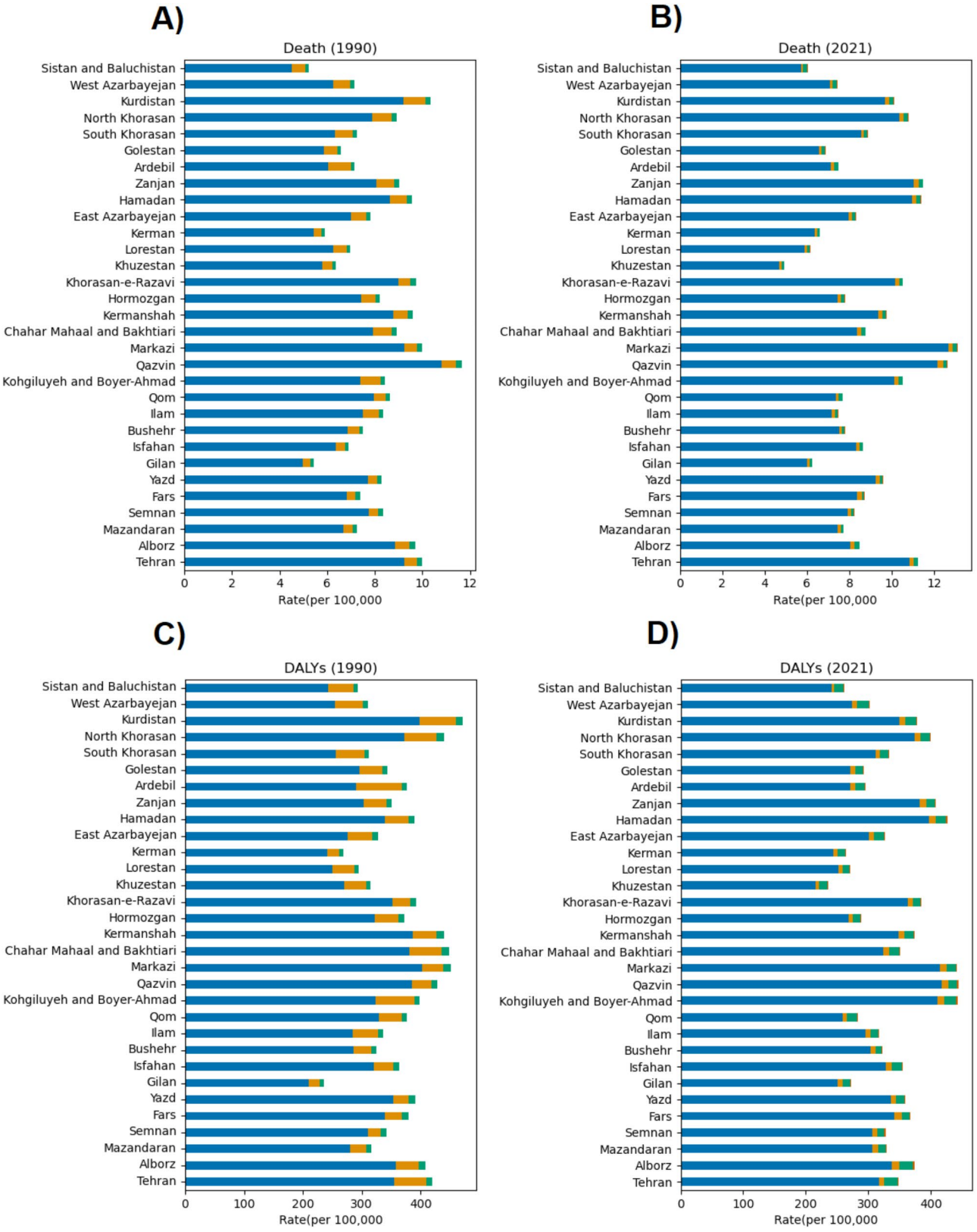

Fig. 6 Rates of (**A**, **B**) death, and (**C**, **D**) disability-adjusted life-years (DALYs) for falls by risk factors among provinces of Iran in 1990 and 2021

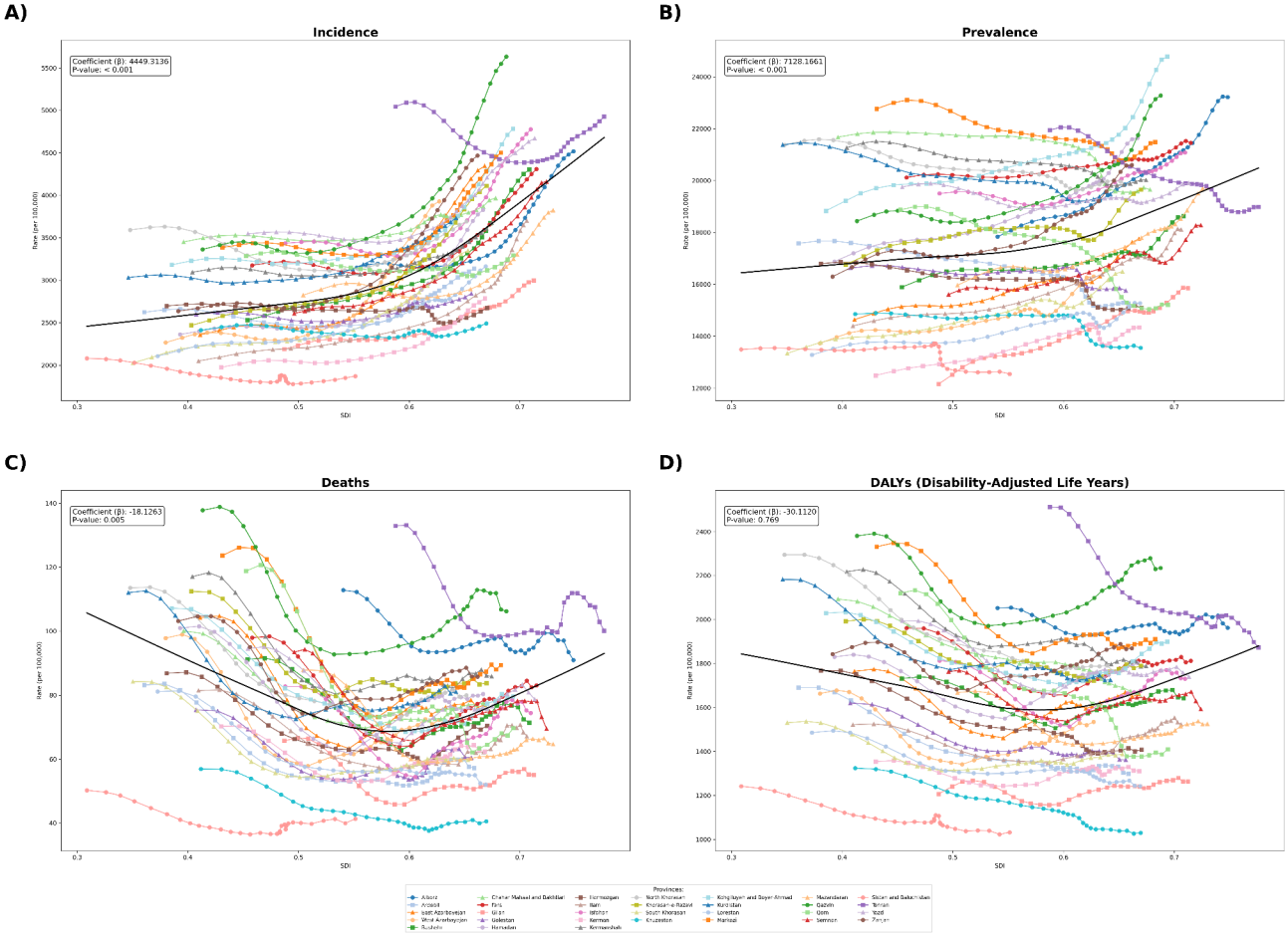

Fig. 7 Association of socio-demographic index (SDI) with (**A**) incidence rate (Coefficient β: 4449.3136, *P*-value < 0.001), (**B**) prevalence rate (Coefficient β: 7128.1661, *P*-value < 0.001), (**C**) death rate (Coefficient β: -18.1263, *P*-value: 0.005), and (**D**) disability-adjusted life-years (DALYs) rate (Coefficient β: -30.1120, *P*-value: 0.769)

while the proportion attributable to other risk factors decreased (Fig. 6).

The association between SDI and the burden of falls

We analyzed the association between SDI and the burden of falls across Iran and its 31 provinces in 2021. As illustrated in Fig. 7, there were significant positive association between SDI and the incidence rate for falls (Coefficient β: 4449.3136, *P*-value < 0.001), as well as SDI and the prevalence rate (Coefficient β: 7128.1661, *P*-value < 0.001). In contrast, SDI had a significant inverse association with the death rate (Coefficient β: -18.1263, *P*-value: 0.005). No significant association was found between SDI and DALYs rate (Fig. 7).

Discussion

The current analysis of the GBD 2021 data represented the burden of falls and its attributable risk factors among older adults in Iran at national and subnational levels over 32 years. Our findings indicated an increase in the national incidence rate of falls among older adults while the DALYs rate decreased. The prevalence and death rates of falls remained almost constant. Moreover, we observed an overall increasing trend in incidence, prevalence, deaths, and DALYs of falls with aging. From 1990 to 2021, males exhibited higher rates of prevalence, deaths, and DALYs related to falls compared to females, while females had a higher incidence rate than males. LBMD was the primary risk factor that contributed the most to the burden of falls. Furthermore, we found significant positive associations between SDI and both the incidence and prevalence rates of falls, as well as a significant inverse association between SDI and the death rate.

One of the primary findings of our study was the increased incidence rate of falls among older adults in Iran, consistent with previous GBD studies from China and Saudi Arabia [28, 34]. By obtaining data from the GBD 2019, Ye et al. explored the burden of falls in older adults at the national and subnational levels in mainland China. They evaluated the trends from 1990 to 2019. They found a substantial increase of 79.2% (65.9–93.7) in the incidence rate of falls among older adults [28].

Likewise, a study by Bindawas et al. analyzed the trends in incidence, prevalence, and DALYs related to falls among the geriatric population in Saudi Arabia from 1990 to 2019, using the GBD 2019 data, and reported a 53% increase in the incidence rate of falls [34]. On the other hand, a global analysis by James et al. utilizing data from the GBD 2017 evaluated the morbidity and mortality from falls and found a slight decline of 3.7% (-7.4–0.3) in the global incidence rate of falls from 1990 to 2017 [35]. The increased incidence rate of falls among older adults in Iran could stem from the country's rapidly aging population [17]. As life expectancy rises and the proportion of older adults grows, the proportion of individuals at risk of falls grows simultaneously.

Moreover, our study found an increasing trend in incidence, prevalence, deaths, and DALYs of falls with aging, highlighting the significant burden of falls in old individuals, which was in line with the body of literature [36–38]. With advancing age, old people experience falls primarily due to a decline in their intrinsic capacity and functional ability because of somatic and psychological health issues, including sarcopenia, osteoporosis, sleeping disturbance, multimorbidity, and frailty [39–42]. Furthermore, increased awareness and better reporting of falls could lead to a higher incidence rate.

Another finding of our study revealed a decrease in the DALYs rate of falls among older adults in Iran, consistent with the global trend, which represented a 13.9% (-21.3-8.0) decline in the falls DALYs rate from 1990 to 2017 [35]. In contrast, a study from China reported an increase of 26.6% (-5.3-46.8) in the DALYs rate from falls among older adults in mainland China from 1990 to 2019, while the results from a study from Saudi Arabia showed an almost constant DALYs rate with a 2% increase among older adults in Saudi Arabia from 1990 to 2019 [28, 34]. It could be hypothesized that the decreased burden from falls in Iran could result from improved healthcare and rehabilitation services across the country over the past decades and increased awareness and preventive measures of falls.

Our results indicated that in Iran in 2021, females had a higher incidence rate of falls than males. Similarly, a Chinese study reported similar results, calculating an incidence rate of 4264.9 (3474.5-5166.7) per 100,000 population for females and an incidence rate of 3294.6 (2618.0-4064.9) per 100,000 population for males in 2019 [28]. In contrast, a Saudi Arabian study found a higher incidence rate of falls in males, reporting an incidence rate of 5271.159 (4521.153-6099.987) per 100,000 individuals for males and an incidence rate of 4172.095 (3635.992-4797.122) per 100,000 individuals for females in 2019 [34]. Despite the different ethnicity and cultural factors that could play an essential role in the disparities between countries, differences in populations might also be a possible explanation since the current study and the Chinese analysis defined older adults as 60 and older. In contrast, the Saudi Arabian study used the 55 and older definition. The higher incidence rate of falls in females compared to males in Iran can be attributed to several factors, including biological, socioeconomic, and environmental factors. Males typically have greater muscle mass and strength, which can enhance balance and stability. Additionally, females may experience more significant declines in strength and balance as they age, contributing to a higher risk of falls [22, 23]. Moreover, females, particularly older females, are more likely to live alone or in less supportive environments than males. This isolation can limit their physical activity and increase the risk of falls due to unsafe living conditions [23]. Furthermore, many females in Iran are homemakers, which may lead to a sedentary lifestyle and reduced physical activity levels. Lack of physical exercise can weaken muscles and impair balance, increasing the risk of falls [22, 23].

We found that males had a higher DALYs rate of falls than females, which was in line with existing literature. Ye et al. estimated a DALYs rate of 1310.6 (937.6-1649.3) per 100,000 persons in males and a DALYs rate of 1172.9 (854.5–1481) in females in 2019 [28]. Similarly, Bindawas et al. calculated a DALYs rate of 1921.658 (1434.397-2458.078) per 100,000 persons in males and a DALYs rate of 875.4675 (672.8409–1125.06) in females in 2019 [34]. The higher DALYs rate of falls in males compared to females could be due to several factors. Males are generally more prone to engage in risk-taking behaviors and hazardous activities, which can lead to a higher burden from falls [43]. Additionally, many males in their working years engage in physically demanding jobs that expose them to environments with a higher risk of falls, such as construction sites, industrial settings, and heavy labor industries. The nature of these occupations often involves working at heights, handling heavy machinery, or performing repetitive strenuous tasks, increasing the likelihood of fall-related disabilities and deaths and contributing to a higher burden. Although the official retirement age in Iran varies depending on occupation and employment sector, with many retiring between 60 and 65 years old, some individuals, particularly in informal labor sectors, continue working beyond the standard retirement age. This prolonged occupational exposure may increase the fall burden among older males [44].

Our findings demonstrated that LBMD was the primary risk factor for falls. Additionally, the impact of LBMD on the burden of falls increased with age, possibly due to age-related osteoporosis, which puts older individuals at a higher risk of disability and death from falls [45]. As people age, their bone mineral density naturally decreases because of an imbalance in bone remodeling. This imbalance is caused by increased bone resorption

and decreased bone formation, leading to progressive bone loss. Additionally, the protective effects of estrogen on bone health in females diminish following menopause, further decreasing bone strength [46].

Our analysis showed significant positive associations between SDI and both the incidence and prevalence rates of falls among the provinces of Iran. Provinces with higher SDI tend to have a longer life expectancy, leading to a higher proportion of older adults, who are at greater risk for falls [47]. This increased proportion of older individuals may result in more reported falls cases, contributing to higher incidence and prevalence rates. Moreover, higher SDI provinces likely have better healthcare infrastructure and medical record systems, which lead to more accurate reporting and documentation of falls. We observed a significant inverse association between SDI and the death rate. As the SDI increased from the baseline to nearly 0.6, the death rate decreased. This trend may be attributed to improved access to healthcare, better emergency response, and enhanced post-fall management in higher SDI provinces. Interestingly, the death rate began to rise again after reaching this point. This phenomenon may be explained by the greater proportion of very old individuals in high SDI provinces due to longer life expectancy [47]. Since this vulnerable population is at a higher risk for falls and related deaths, we may observe this increase in the death rate.

In 2021, the World Health Organization (WHO) published a comprehensive report providing integrated strategies to prevent and manage falls across all ages [39]. While these global strategies are valuable, their implementation should be tailored to the Iranian context, considering variations in socioeconomic status, healthcare access, and cultural factors. To reduce the incidence and burden of falls in older adults in Iran, targeted interventions based on age, sex, and socioeconomic level should be prioritized. Women should be more actively involved in physical activity interventions, including strength training, balance exercises, and structured community-based exercise programs to counteract sarcopenia and osteoporosis, which increase fall risk. Encouraging participation in culturally appropriate group exercise programs, such as outdoor fitness groups in parks, could enhance engagement. Men, particularly those with a history of physically demanding occupations, may benefit from post-retirement physical therapy and muscle-strengthening programs to reduce occupational-related musculoskeletal degeneration and balance issues. Socioeconomically disadvantaged older adults, particularly in rural areas, may have limited access to fall prevention resources. Community-based initiatives should prioritize free or subsidized home safety modifications, such as installing grab bars, improving home lighting, and providing non-slip flooring materials, particularly for those at higher risk of severe fall-related injuries. Public awareness campaigns should focus on educating caregivers and families about fall risks, especially in multi-generational households, which are common in Iran. Assistive devices, such as canes and walkers, should be made more affordable and accessible, with government subsidies or insurance coverage for low-income individuals. Medication management programs should be integrated into primary healthcare centers, ensuring regular medication reviews to minimize polypharmacy and the use of sedative medications that increase fall risk [39].

Additionally, Multifactorial Risk Assessments (MRAs) should be routinely conducted in Iranian healthcare facilities to identify high-risk individuals and provide personalized fall prevention interventions. Establishing Fracture Liaison Services (FLS) across major Iranian hospitals could systematically improve osteoporosis management and post-fall rehabilitation, ultimately reducing fall-related disabilities and deaths [48]. Strengthening these localized interventions within Iran's existing healthcare and community infrastructure can significantly reduce the incidence and burden of falls among older adults.

Strengths and limitations

The study's strength lies in its thorough analysis, which obtained the most recent data from the GBD dataset. It provided a robust estimation of the changing epidemiology and burden of falls among older adults in Iran and its 31 provinces from 1990 to 2021, stratified by sex, age, and SDI. Despite the strengths of this study, several limitations should be acknowledged. First, there may be inconsistencies in data collection methods, accuracy, and completeness, particularly at the subnational level. Second, falls among older adults might be underreported, especially in rural areas or regions with limited healthcare access. Third, misclassification of causes of disability or death related to falls may occur. Fourth, the GBD uses statistical modeling to estimate the burden of falls, which involves assumptions and imputations that may not entirely reflect the actual burden. These models might oversimplify complex realities, which could lead to potential biases. Fifth, the methods used to attribute risk factors to falls are based on established epidemiological associations, which may vary in different populations and contexts, potentially leading to inaccuracies in risk factor attribution [24–26].

Conclusions

The current epidemiological study of falls among the Iranian older adult population from 1990 to 2021 revealed essential insights. Although the national DALYs rate of falls has decreased among older adults in Iran since 1990, the considerable increase in the incidence rate of falls underscores the importance of falls as a serious and

growing health concern, calling the need for implementing nationwide, cost-effective and integrated strategies, tailored to Iranian older adults to prevent falls and reduce their burden. The data and trends of this study also emphasize the age groups and provinces that are in priority for these interventions. Future research could further stratify data by specific socioeconomic and age-group factors at the provincial level to identify key drivers of disparities in the burden of falls across Iran. Additionally, exploring the indirect contribution of chronic diseases to the burden of falls may provide deeper insights into their role in fall prevention and risk mitigation strategies.

Abbreviations

CODEm	Cause of Death Ensemble model
CRA	Comparative Risk Assessment
DALY	Disability-adjusted Life-year
DXA	Dual-energy X-ray Absorptiometry
FLS	Fracture Liaison Services
GATHER	Guidelines for Accurate and Transparent Health Estimates Reporting
GBD	Global Burden of Diseases, Injuries, and Risk Factors Study
ICD	International Classification of Diseases
LBMD	Low Bone Mineral Density
MRA	Multifactorial Risk Assessment
PAF	Population-attributable Fraction
PC	Percentage Change
SDI	Socio-demographic Index
TMREL	Theoretical Minimum Risk Exposure Level
UI	Uncertainty Interval
WHO	World Health Organization
YLD	Years Lived with Disability
YLL	Years of Life Lost

Supplementary Information

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Supplementary Material 1

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Author contributions
HG, MAK, AG, and SHG designed the study. MAK analyzed the data and performed statistical analyses. AG developed and validated the methodology. HG drafted the initial manuscript. MN, AG, SK, MRM, OTM, NR, AO, and SHG critically edited and revised the initial draft of the manuscript. SHG supervised the project. All authors reviewed the drafted manuscript for critical content. All authors approved the final version of the manuscript.

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Data availability
The data used for the current analysis is publicly available at https://vizhub.healthdata.org/gbd-results/.

Declarations

Ethics approval and consent to participate
This research was conducted in accordance with the principles outlined in the Declaration of Helsinki. The findings are derived from estimates provided by the GBD 2021 and comply with applicable guidelines and regulations. This study was approved by the review board of the Endocrinology and Metabolism Research Institute at Tehran University of Medical Sciences (IR.TUMS.EMRI.REC.1401.166)

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The authors declare no competing interests.

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