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A spatiotemporal analysis of incidence and mortality rate due to falls in Iran from 2010 to 2019

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Abstract

Background As the population ages, the incidence of falls and related injuries has become increasingly prominent, posing significant challenges to healthcare systems and negatively affecting the quality of life of the elderly. This study investigated the trend and spatiotemporal analysis of the age-standardized incidence and mortality rates of falls in Iran, specifically from 2010 to 2019.

Methods An ecological study was conducted based on data from the IHME site for ten years, from 2010 to 2019. The annual age-standardized incidence and mortality rates per 100,000 individuals due to falls were calculated. A spatiotemporal statistical analysis was used to determine the geographical and temporal distribution.

Findings Age-standardized incidence and mortality rates have decreased over ten years. Chahar Mahaal and Bakhtiari, Semnan, and Qazvin have reported the highest prevalence in both sexes, men and women. The death rate in Qazvin province for both sexes and men and Alborz province for women ranks first. According to the hotspot analysis results, Fars province has the highest incidence rate, and Kermanshah province has the highest death rate.

Conclusion Population aging in Iran is a health-treatment challenge. Falling is one of the consequences of this challenge. The southern and western provinces allocate the highest age-standardized incidence and mortality rates. Ensuring equitable access to health care services for the target population is recommended to be a priority for politicians.

Keywords Fall, Spatiotemporal, Incidence rate, Mortality rate, IRAN

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Introduction

The aging of the population is accompanied by a decrease in musculoskeletal function, one of which is falling. The associated injuries reduce the quality of life of the elderly. According to the World Health Organization, it is expected that in 2050, the population aged 60 years and older will reach 22%. Therefore, falls are one of the significant challenges for the healthcare system [1, 2].

Falls are the leading cause of both fatal and non-fatal injuries among older adults. Research indicates that approximately one-third of individuals aged 65 years and older living in the community experience a fall annually, with this proportion increasing to nearly 50% among those aged 80 and above [3, 4]. Reports show that Oceania has the highest rate of falls in older adults worldwide (34.4%), and America has the next highest (27.9%) [5]. Available reports indicate a high prevalence of falls and fear of falling among Iranian older adults. Therefore, policymakers, nursing home officials, elderly nurses, and elderly companions must recognize risk factors and implement necessary measures to maintain safety [6].

In Iran, the number of falls among older people over the course of ten years (2007-2017) was 1.9, the rate of falls was 32%, and the fear of falling was 41%. The incidence of falls in nursing homes was 36% higher compared to home residents [6]. Recent statistics in Iran show that after injuries caused by traffic accidents and trauma, the incidence of falls from height is the highest, with 195.2 per 100,000 people [7].The results of a cohort study in Ardakan County, Yazd Province, showed that among 4,990 people over 50 years of age, the prevalence of falls was 19.9% , and the prevalence of more than two falls was 10.1%. This occurrence was also reported more frequently in women and older people. The prevalence of fractures following falls was 5.1% in men and 8.6% in women [8].

The consequences of falls are severe, including significant medical costs and long-term care expenses. This highlights the urgent need for effective prevention strategies and targeted public health interventions to address this growing issue [9, 10]. Previous studies have reported that falls are a leading cause of injury and death in the elderly population, with substantial regional differences influencing the overall burden of these incidents [11]. Falls are the second leading cause of unintentional injury deaths worldwide. Four hundred twenty-four thousand people worldwide die from falls, with a reported rate of 4.6 per cent in Iran [12, 13]. In addition, the age-standardized death rate (ASDR) decreased in Iran due to the fall from 2.61 per 100,000 people in 1990 to 2.13 in 2015 [14].

One in three older adults over the age of 65 and two in two older adults over the age of 80 will experience at least one fall. Older adults who experience falls will develop a fear of falling, post-fall anxiety syndrome, depression, and reduced activity, which negatively impacts their quality of life [15]. Overall, this event causes irreversible harm, including morbidity with a variety of comorbidities, mortality, and an increased burden on the health system due to the problems of ageing. Therefore, health authorities and policymakers must understand the fall trend and its causes and develop prevention strategies to reduce falls and their costs [16, 17].

In Iran, the incidence and mortality rate of falls among older adults has been a rising concern. National health data indicate significant variation in fall rates across provinces due to environmental factors, socioeconomic inequalities, and access to healthcare [18]. It also emphasizes the need for detailed spatiotemporal analysis to understand regional patterns and develop appropriate preventive measures [19]. This ecological study aims to perform a comprehensive spatiotemporal analysis of Iran's annual age-standardized incidence and mortality rates from 2010 to 2019. It is hoped that the results of this study will be effective in prioritizing health care programs for older adults, keeping in mind environmental factors, to reduce the incidence of falls and their consequences.

Method

This ecological study was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (Ethics Code: IR.SBMU.PHNS.REC.1403.077). The Institute for Health Metrics and Evaluation (IHME) delivers timely, relevant, and scientifically valid evidence to improve health policy and practice worldwide, including in Iran. [20]. On the IHME website, we selected the option "Cause of death or injury" in the section "GBD Estimate" and the option "Falls" in the section "Cause" from the subgroup "unintentional injuries". Then, an Excel file containing evidence of Iran's declining trend by gender and province was extracted. This enabled the ecological study to examine the age-standardized incidence and mortality rates per 100,000 population from 2010 to 2019.

Temporal trend analysis

A line graph of the trend of age-standardized incidence and mortality (per 100,000 people) was drawn using Excel software. And using Stata software, a 95% confidence interval was calculated.

Descriptive map

First, we prepared a descriptive table based on each province's FID. Then, we entered the average age-standardized incidence and mortality rates for the periods 2010-2014 (first period) and 2015-2019 (second period) and over ten years (2010-2019) in both sexes separately. We drew descriptive maps using ArcMap 10.8 software.

Hot spot analysis

Our research employed the Getis-Ord Gi statistic to meticulously determine the grouping of fall incidence and mortality in two five-year periods, from 2010 to 2014 and from 2015 to 2019, in both sexes—a tool where an increased index score with a decreased p-value indicates the clustering of the studied events. The formula for the Gi statistic is as follows:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j}x_j - \overline{X}\sum_{j=1}^{n} w_{i,j}}{S\sqrt{\frac{n\sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j}\right)^2}{n-1}}} \quad (1)$$

The mortality rate of understudy events for province j, weight between provinces i and j, and n is the to brovinces. X and, S are calculated as follows:

$$\overline{X} = \frac{\sum_{j=1}^{n} x_j}{n}, \quad S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\overline{X})^2}. \quad (2)$$

In terms of hot spot analysis, α: 0.01 and 0.05 were considered significant levels.

Results

Descriptive analysis

Table 1 shows that both sexes'age-standardized incidence and mortality rates decreased from 2010 to 2019. The incidence rate in males and females in 2010 decreased from 3013.46 and 1468.85 to 2774.52 and 1372.18 in 2019, respectively. The mortality rate in men decreased from 6.11 to 5.34 and in women from 3.21 to 2.90 between 2010 and 2019 (Figs. 1 and 2). Based on the results, the overall male-to-female incidence and mortality ratio during these ten years was 2.03 and 1.87, respectively.

Descriptive map

Both sexes

Age-standardized incidence rate The highest incidence rates of falls occurred from 2010 to 2014 in the southwestern provinces of Kohgiluyeh and Boyer-Ahmad, Fars

Table 1 Age-standardized incidence and mortality rate due to falls per 100,000 individuals by gender in Iran between 2010 and 2019

		Age-standardized incidence rate (95% CI)[a]				Age-standardized mortality rate (95% CI)			
Christian year	Persian year	Both sexes	Male	Female	M/F[b]	Both sex	Male	Female	M/F
2010	1389	2247.1 (1915.95–2655.97)	3013.46 (2560.52–3547.55)	1468.85 (1225.01–1766.16)	2.05	4.67 (4.04–6.17)	6.11 (5.32- 8.42)	3.21 (2.53–4.34)	1.9
2011	1390	2219.62 (1902.19–2613.97)	2975.78 (2538.81–3486.97)	1452.87 (1212.8–1741.98)	2.05	4.61 (3.97–6.12)	6.03 (5.24–8.38)	3.17 (2.50–4.34)	1.91
2012	1391	2186.32 (1881.22–2566.97)	2927.45 (2507.82–3415.39)	1435.22 (1198.08–1716.62)	2.04	4.57 (3.92–6.07)	5.99 (5.16–8.36)	3.15 (2.47–4.33)	1.9
2013	1392	2152.42 (1856.53–2522.08)	2876.77 (2472.1–3343.75)	1417.68 (1187.32–1691.01)	2.03	4.57 (3.93–6.04)	5.96 (5.09–8.24)	3.18 (2.49–4.35)	1.88
2014	1393	2122.99 (1834.73–2483.37)	2832.06 (2442.43- 3284.91)	1402.08 (1176.42–1668.37)	2.02	4.49 (3.84–6.04)	5.84 (4.98–8.35)	3.13 (2.46- 4.27)	1.87
2015	1394	2102.97 (2455.05-1820.8)	2801.62 (2428.84- 3237.52)	1390.35 (1166.09–1657.01)	2.02	4.39 (3.73–5.99)	5.71 (4.79–8.22)	3.07 (2.39–4.31)	1.86
2016	1395	2091.48 (1814.77–2438.59)	2784.69 (2417.84- 3216)	1382.05 (1159.23–1639.26)	2.01	4.31 (5.86-3.67)	5.58 (4.68- 8.09)	3.04 (2.40–4.18)	1.84
2017	1396	2084.48 (1812.94–2423.95)	2774.79 (2415.48–3197.48)	1375.87 (1154.27–1629.03)	2.02	4.25 (3.62–5.85)	5.50 (4.59–7.97)	3 (2.36–4.14)	1.83
2018	1397	2082.2 (1815.03–2414.48)	2771.55 (2420.78–3191.27)	1372.38 (1152-1622)	2.02	4.17 (3.52–5.67)	5.41 (4.50–7.77)	2.93 (2.30–4.08)	1.84
2019	1398	2084.72 (2409.04-1819.21)	2774.52 (2428.34–3189.41)	1372.18 (1153.37–1617.12)	2.02	4.12 (3.50–5.7)	5.34 (4.47–7.83)	2.90 (2.27–4.05)	1.84

[a] Confidence Interval

[b] Male/Female

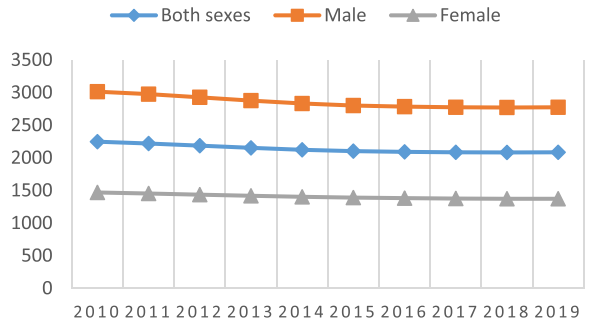


Fig. 1 Age- standardized incidence rate due to falls by gender in Iran between 2010 and 2019

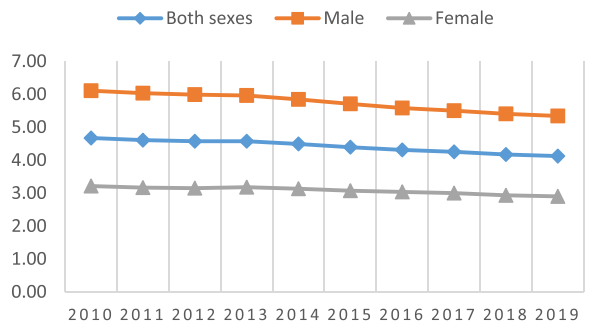


Fig. 2 Age- standardized mortality rate due to falls by gender in Iran between 2010 and 2019

in southern Iran, and the two central provinces, Alborz and Markazi, respectively (2902.36, 95% CI: 2490.00–3377.33), (2786.74, 95% CI: 2380.75–3275.16), (2637.66, 95% CI: 2257.60–3106.55), (2626.44, 95% CI: 2239.30–3090.27) (Fig. 3.a). In the second period, the provinces of the first period, except for the Markazi Province, were still in the very high density group (Kohgiluyeh and Boyer-Ahmad: 2963.57, 95% CI: 2572.64–3425.67), (Fars: 2718.97, 95% CI: 2352.81–3161.54), (Alborz: 2679.02, 95% CI: 2331.85–3083.39) (Fig. 3.b). Over the 10 years, the highest provinces remained the same as in the second period: Kohgiluyeh and Boyer-Ahmad, Fars, and Alborz, respectively (Table 2, Fig. 3.c).

Age-standardized mortality rate In the first period, Qazvin, Khorasan-e-Razavi, Alborz, and Hamedan provinces had the highest density, respectively (6.24, 95% CI: 3.94–7.39), (5.89, 95% CI: 4.62–6.63), (5.82, 95% CI: 3.89–7.01), (5.72, 95% CI: 4.62–7.28) (Fig. 4.a). From 2015 to 2019, Qazvin, Alborz, Khorasan-e-Razavi, North Khorasan, and Hamedan provinces were in the very high-density group, respectively (5.93, 95% CI: 3.72–7.11), (5.47, 95% CI: 3.77–6.73), (5.25, 95% CI: 4.12–6.06), (5.21, 95% (3.88–6.14) (Fig. 4.b). Over the 10 years, a similar pattern was observed as in the second period (Table 3, Fig. 4.c).

Male

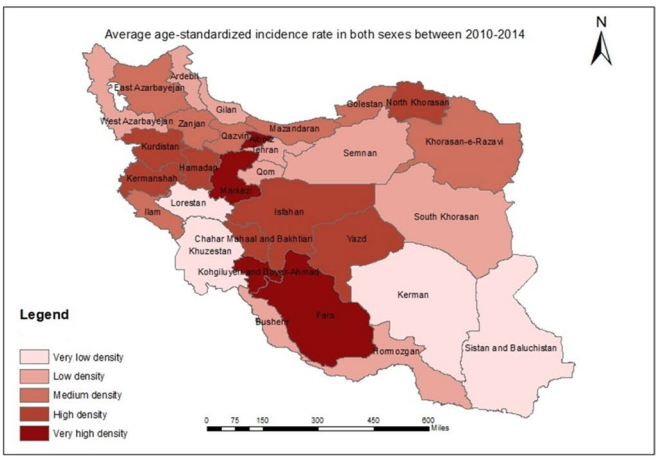
Age-standardized incidence rate From 2010 to 2014, the highest incidence rate of falls in males was in Fars (3916.78, 95% CI: 3328.35–4624.58), Kohgiluyeh and Boyer-Ahmad (3812.72, 95% CI: 4432.32–4468.33), Alborz (3741.28, 95% CI: 3177.11–4419.31), Chaharmahal and Bakhtiari (3485.40, 95% CI: 2986.40–4043.24)), Hamedan (3455.82, 95% CI: 2329.77–4038.48)) and finally Markazi province (3446.63, 95% CI: 2906.65–4066.57)) (Fig. 5.a). In the second period, Kohgiluyeh and Boyer-Ahmad provinces rose from second to first place (3856.36, 95% CI: 3330.38–4493.38). Also, the incidence rate increased in Fars and Alborz provinces (Fars: 3822.77, 95% CI: 3300.39–4448.34), (Alborz: 3822.51, 95% CI: 3314.06–4405.04). The incidence rate decreased slightly in Hamadan province (3499.16, 95% CI: 3018.15–4027.32). Between 2015 and 2019, East Azerbaijan province was also among the provinces with very high density (3822.77, 95% CI: 2296.62–3047.62). In addition, Markazi and Chaharmahal and Bakhtiari provinces also went from very high density in the first half to high density (Fig. 5.b). Overall, over the ten years, the highest incidence rate was reported in Fars province, followed by Kohgiluyeh and Boyer-Ahmad, and Alborz provinces, respectively (Table 2, Fig. 5.c).

Age-standardized mortality rate The highest mortality rates were shown in Qazvin and Khorasan-e-Razavi provinces between 2010-2014, respectively ((8.27, 95% CI: 5.48–9.90), (8.00, 95% CI: 5.92–9.32). Hamedan, Zanjan, Kurdistan, Chahar Mahaal and Bakhtiari, Alborz, and North Khorasan provinces were ranked next (7.93, 95% CI: 6.34–9.68), (7.77, 95% CI: 5.82–9.51), (7.55, 95% CI: 6.15–9.91), (7.55, 95% CI: 6.63–11.38), (7.49, 95% CI: 5.73–11.42), (7.47, 95% CI: 6.63–10.80) (Fig. 6.a).

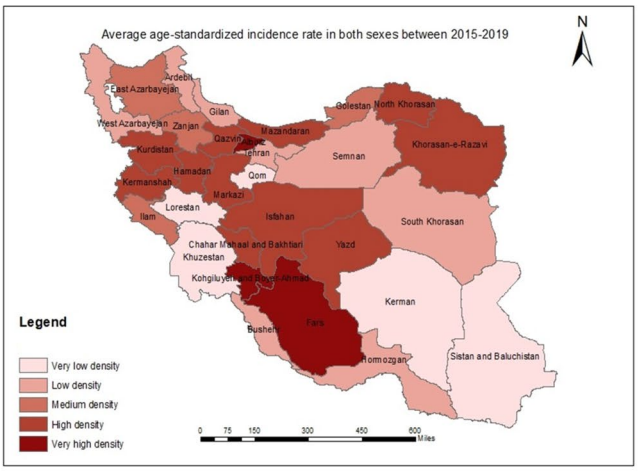
In the second period, the mortality rates in the above provinces decreased. However, Qazvin and Zanjan provinces had the highest rates (7.85, 95% CI: 5.16–9.52), (7.16, 95% CI: 5.26–9.12), and Hamadan, Khorasan-e-Razavi, Chahar Mahaal and Bakhtiari and Alborz were ranked next in the very high density position, respectively (7.09, 95% CI: 5.67–9.11), (7.08, 95% CI: 5.13–8.54), (7.00, 95% CI: 4.91–9.07), (7.00, 95% CI: 4.29–9.07) (Fig. 6.b)

Over the ten years, the four provinces of Qazvin, Khorasan-e-Razavi, Hamedan, and Zanjan had the highest rates (Table 3, Fig. 6.c).

a: Average age-standardized incidence rate due to falls per 100,000 individuals in both sexes in Iran provinces between 2010-2014



b: Average age-standardized incidence rate due to falls per 100,000 individuals in both sexes in Iran provinces between 2015-2019



c: Average age-standardized incidence rate due to falls per 100,000 individuals in both sexes in Iran provinces over 10 years

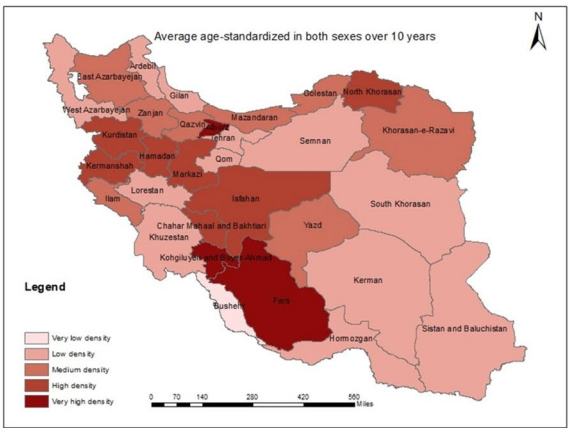


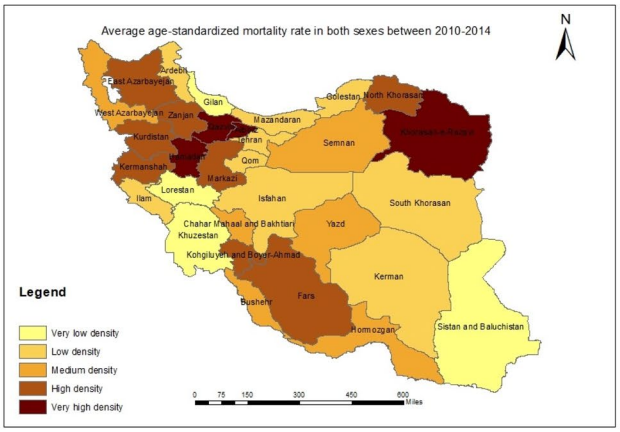
Fig. 3 **a** Average age-standardized incidence rate due to falls per 100,000 individuals in both sexes in provinces of Iran between 2010-2014. **b** Average age-standardized incidence rate due to falls per 100,000 individuals in both sexes in provinces of Iran between 2015-2019. **c** Average age-standardized incidence rate due to falls per 100,000 individuals in both sexes in provinces of Iran over 10 years

Table 2 Average age-standardized incidence rate due to falls per 100,000 people by gender in provinces of Iran between 2010 and 2019

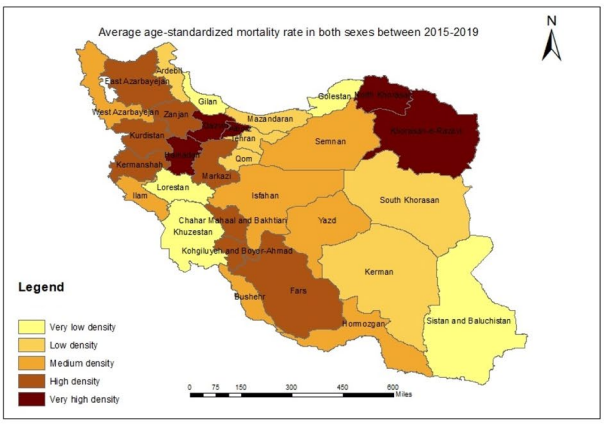
ID	provinces	Age-standardized incidence rate (95% CI[a])				
	Both sexes		Male		Female	
1	Kohgiluyeh and Boyer-Ahmad	2932.97 (2366.78–3218.35)	Fars	3869.77 (3314.37–4536.46)	Kohgiluyeh and Boyer-Ahmad	2043.73 (1742.5–2361.08)
2	Fars	2752.85 (2294.72–3094.97)	Kohgiluyeh and Boyer-Ahmad	3834.54 (3287.35–4480.86)	Markazi	1717.47 (1455.99–2020.84)
3	Alborz	2658.34 (21.73.48–2944.27)	Alborz	3781.90 (3245.59–4412.17)	North Khorasan	1660.53 (1401.73–1952.22)
4	Markazi	2523.74 (2161.77–2919.93)	Hamadan	3477.49 (2970.96–4032.9)	Kermanshah	1637.17 (1395.98–1918.65)
5	Hamadan	2515.50 (2141.8–2894.83)	Chahar Mahaal and Bakhtiari	3388.70 (2921.04–3922.63)	Fars	1602.60 (1341.36–1902.02)
6	Kermanshah	2483.55 (2057.9–2811.37)	Kermanshah	3311.63 (2854.11–3861.25)	Qazvin	1597.88 (1928.81–2575.61)
7	Isfahan	2400.75 (2064.15–2790.86)	Markazi	3298.97 (2821.14–3860.58)	Isfahan	1553.68 (1292.04–1855.38)
8	North Khorasan	2396.45 (2015.96–2722.79)	Kurdistan	3248.65 (2785.31–3759.54)	Tehran	1545.35 (1282.37–1867.9)
9	Chahar Mahaal and Bakhtiari	2376.63 (2050.17–2780.26)	Isfahan	3230.11 (2757.57–3781.1)	Alborz	1533.45 (1283.51–1815.98)
10	Kurdistan	2346.70 (1974.16–2681.54)	North Khorasan	3141.99 (2694.97–3660.92)	Hamadan	1531.04 (1295.71–1807.56)
11	Yazd	2293.57 (1944.99–2650.61)	Mazandaran	3112.54 (2682.75–3634.53)	Yazd	1505.41 (1259.57–1789.84)
12	Mazandaran	2261.73 (1938.72–2621.82)	Ilam	3018.72 (2576.6–3509.23)	Khorasan-e-Razavi	1479.73 (1246.24–1754.02)
13	Khorasan-e-Razavi	2252.66 (1928.81–2575.61)	Yazd	3018.66 (2594.19–3514.52)	Kurdistan	1424.97 (1190.1–1681.97)
14	Qazvin	2230.30 (1832.7–2509.12)	Khorasan-e-Razavi	3016.80 (2590.1–5303.61)	East Azarbayejan	1407.73 (1175.83–2671.95)
15	Ilam	2146.67 (1785.66–2446.31)	Golestan	3001.13 (2561.37–3494.16)	Bushehr	1394.42 (1167.62–1643.43)
16	Golestan	2089.45 (1787.95–2403)	Qazvin	2830.74 (2446.95–3271.4)	Mazandaran	1392.21 (1158.81–1661.44)
17	Zanjan	2064.61 (1770.9–2402.79)	Gilan	2793.09 (2388.18–3262.97)	Zanjan	1377.73 (1155.14–1642.26)
18	East Azarbayejan	2057.50 (1693.34–2304.63)	Zanjan	2734.98 (2365.39–3164.79)	Chahar Mahaal and Bakhtiari	1335.18 (1103–1623.22)
19	West Azarbayejan	1966.94 (1670.32–2310.09)	Hormozgan	2723.13 (2331.58–3184.93)	West Azarbayejan	1325.04 (1112.09–1582.06)
20	Gilan	1957.43 (1669.35–2288)	East Azarbayejan	2681.22 (2311.76–3118)	Semnan	1273.73 (1064.35–1525.47)
21	Hormozgan	1946.33 (1652.18–2285.75)	Ardebil	2670.42 (2318.16–3106.33)	Qom	1261.92 (1032.9–1524.56)
22	Tehran	1942.13 (1647.3–2262.74)	West Azarbayejan	2584.84 (2209.8–3018.32)	Ilam	1247.41 (1038.65–1491.2)
23	Ardebil	1921.20 (1616.81–2214.04)	South Khorasan	2574.21 (2201.97–2999.69)	South Khorasan	1185.67 (979.77–1422.05)
24	South Khorasan	1892.18 (16.31.36–2204.27)	Khuzestan	2474.88 (2122.47–2891.41)	Golestan	1167.76 (962.97–1410.85)
25	Semnan	1883.95 (1600.03–2193.6)	Semnan	2466.53 (1631.36–2204.27)	Lorestan	1137.70 (920.89–1380.13)
26	Qom	1868.05 (1543.39–2123.46)	Qom	2465.10 (2118.98–2877.85)	Hormozgan	1137.48 (941.49–1371.91)
27	Khuzestan	1806.98 (1528.69–2128.76)	Kerman	2444.59 (2074.49–2862.67)	Kerman	1137.45 (936.05–1379.25)
28	Kerman	1804.61 (1473.76–2027.43)	Tehran	2357.26 (2014.16–2749.76)	Ardebil	1136.06 (918.11–1382.87)
29	Lorestan	1722.29 (1967.26-1428.66)	Lorestan	2293.26 (1974.67–2672.48)	Khuzestan	1127.75 (917.75–1375.98)
30	Sistan and Baluchistan	1670.95 (163.15–218.78)	Bushehr	2273.03 (1964.89–2631.79)	Sistan and Baluchistan	1113.53 (927.96–1335.03)
31	Bushehr	188.06 (20501.7–27802.62)	Sistan and Baluchistan	2235.27 (1912.12–2624.6)	Gilan	1112.85 (904.04–1378.07)

[a] Confidence interval

a: Average age-standardized mortality rate due to falls per 100,000 individuals in both sexes in Iran provinces between 2010-2014



b: Average age-standardized mortality rate due to falls per 100,000 individuals in both sexes in Iran provinces between 2015-2019



c: Average age-standardized mortality rate due to falls per 100,000 individuals in both sexes in Iran provinces over 10 years

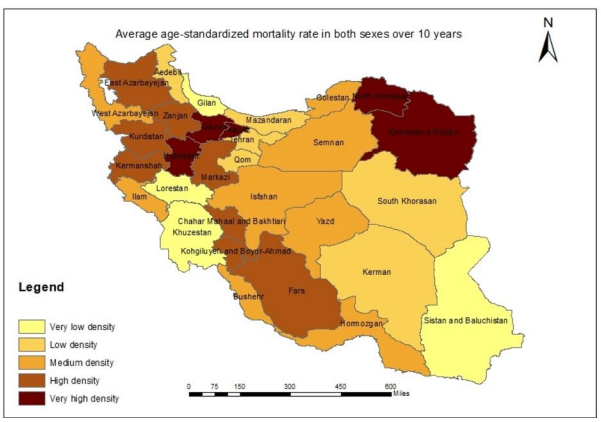


Fig. 4 **a** Average age-standardized mortality rate due to falls per 100,000 individuals in both sexes in provinces of Iran between 2010-2014. **b** Average age-standardized mortality rate due to falls per 100,000 individuals in both sexes in provinces of Iran between 2015-2019. **c** Average age-standardized mortality rate due to falls per 100,000 individuals in both sexes in provinces of Iran over 10 years

Table 3 Average Age-standardized mortality rate due to falls per 100,000 individuals by gender in provinces of Iran between 2010 and 2019

ID	provinces	Age-standardized mortality rate (95% CI[a])				
	Both sexes		Male		Female	
1	Qazvin	6.09 (3.83–7.25)	Qazvin	8.06 (5.32–9.71)	Alborz	4.40 (3.21–5.42)
2	Alborz	5.65 (3.83–6.87)	Khorasan-e-Razavi	7.54 (5.52–8.93)	Qazvin	4.11 (2.17–5.2)
3	Khorasan-e-Razavi	5.57 (4.37–6.35)	Hamadan	7.51 (6.01–9.39)	Markazi	3.82 (2.4–5.08)
4	Hamadan	5.46 (4.43–7.08)	Zanjan	7.47 (5.54–9.31)	North Khorasan	3.78 (2.67–4.59)
5	North Khorasan	5.41 (3.99–6.31)	Chahar Mahaal and Bakhtiari	7.27 (5.14–9.26)	Kermanshah	3.73 (4.66-2.76)
6	Zanjan	5.25 (3.80–6.88)	Alborz	7.24 (4.38–9.28)	Kohgiluyeh and Boyer-Ahmad	3.68 (4.57-2.47)
7	Kermanshah	5.21 (4.35–6.32)	North Khorasan	7.13 (5.13–8.60)	Khorasan-e-Razavi	3.61 (2.81–4.35)
8	Kohgiluyeh and Boyer-Ahmad	5.20 (3.88–6.10)	Fars	7.05 (5.87–8.62)	Tehran	3.57 (2.03–4.72)
9	Fars	5.16 (6.32-4.45)	Kurdistan	7.02 (5.55–9.56)	East Azarbayejan	3.51 (2.84–4.79)
10	Kurdistan	5.15 (4.05–6.92)	Kohgiluyeh and Boyer-Ahmad	6.77 (5.04–8.18)	Hamadan	3.48 (2.52–5.11)
11	Markazi	5.07 (3.76–6.85)	Kermanshah	6.75 (5.57–8.52)	Qom	3.43 (2.74–4.96)
12	East Azarbayejan	4.84 (4.07–6.39)	Markazi	6.38 (4.87–9)	Kurdistan	3.27 (2.27–4.92)
13	Chahar Mahaal and Bakhtiari	4.73 (3.54–6.69)	East Azarbayejan	6.15 (5.02–8.48)	Fars	3.26 (2.61–4.69)
14	Yazd	4.59 (3.83–5.75)	Hormozgan	6.14 (5.03–8.45)	Isfahan	3.24 (2.44–4.77)
15	West Azarbayejan	4.52 (3.64–6.47)	Semnan	6.00 (4.83–7.62)	Yazd	3.22 (2.48–4.24)
16	Bushehr	4.33 (3.52–5.65)	Yazd	5.96 (4.84–7.81)	West Azarbayejan	3.20 (2.48–4.79)
17	Semnan	4.33 (3.57–5.48)	Ilam	5.95 (4.77–8.38)	Bushehr	3.14 (3.94-2.26)
18	Hormozgan	4.33 (5.91-3.62)	Golestan	5.94 (4.94–8.06)	Zanjan	3.09 (2–4.81)
19	Ilam	4.24 (3.46–5.91)	West Azarbayejan	5.85 (4.6–8.74)	Semnan	2.71 (2.08–4.02)
20	Isfahan	4.19 (3.40–6.43)	Ardebil	5.71 (4.48–8.46)	Mazandaran	2.63 (2.03–4)
21	Golestan	4.15 (3.42–5.71)	South Khorasan	5.47 (4.31–8.37)	Ilam	2.53 (1.96–4.06)
22	Mazandaran	3.98 (3.27–5.37)	Bushehr	5.38 (4.36–7.69)	Hormozgan	2.50 (1.95–4.04)
23	Tehran	3.93 (2.92–6.01)	Mazandaran	5.34 (4.24–7.32)	Kerman	2.49 (1.68–4.86)
24	Qom	3.86 (2.99–6.21)	Isfahan	5.16 (4–8.4)	Golestan	2.41 (1.77–4.08)
25	Kerman	3.80 (2.96–6.59)	Kerman	5.07 (3.53)	Chahar Mahaal and Bakhtiari	2.30 (1.64–4.71)
26	South Khorasan	3.77 (3–5.96)	Gilan	4.83 (3.64–7.83)	South Khorasan	2.12 (1.51–4.26)
27	Ardebil	3.75 (2.86–5.88)	Lorestan	4.71 (3.24–8.34)	Lorestan	2.07 (1.39–4.34)
28	Gilan	3.37 (2.49–5.65)	Qom	4.64 (3.35–8.15)	Sistan and Baluchistan	2.02 (1.3–4.25)
29	Lorestan	3.37 (2.36–6.03)	Sistan and Baluchistan	4.59 (3.06–8.26)	Gilan	1.94 (1.21–4.07)
30	Sistan and Baluchistan	3.30 (2.25–5.85)	Tehran	4.34 (2.86–8.38)	Ardebil	1.84 (1.15–4.09)
31	Khuzestan	2.82 (1.91–5.24)	Khuzestan	3.97 (2.73–7.36)	Khuzestan	1.67 (1–3.63)

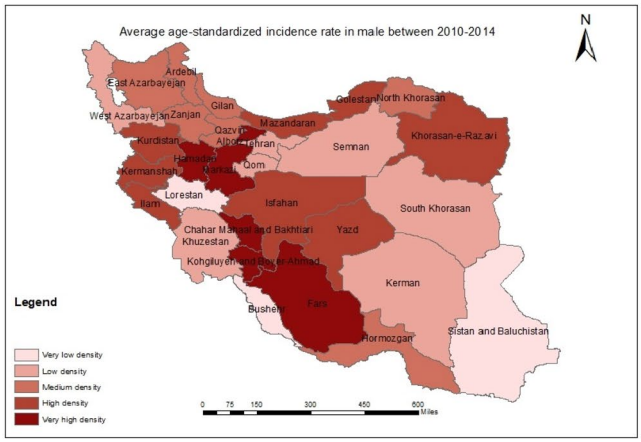
[a] Confidence interval

Female

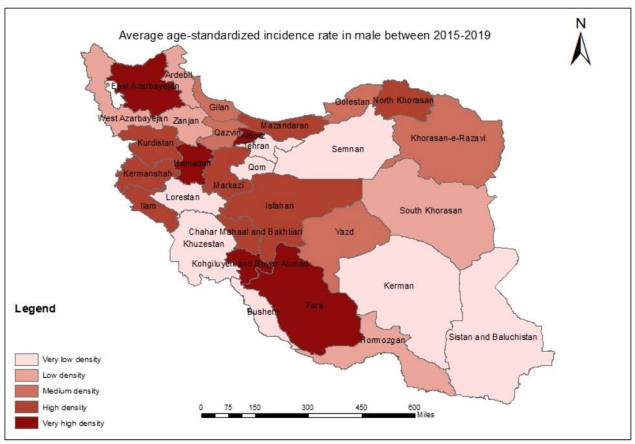
Age-standardized incidence rate Between 2010 and 2014, Kohgiluyeh and Boyer-Ahmad, and Markazi provinces had the highest incidence rates, respectively (2023.31, 95% CI: 1716.26–2345.39), (1776.75, 95% CI: 1503.19–2099.41) (Fig. 7.a). In the second period, only Golestan province was in the very high density category (5649.79, 95% CI: 938.31–1358.89) (Fig. 7.b). From 2010 to 2019, Kohgiluyeh and Boyer-Ahmad province ranked highest with an incidence rate (2043.73, 95% CI: 1742.50–2361.08), while Markazi in the high density group, and Golestan in the very low-density group (Table 2, Fig. 7.c).

Age-standardized mortality rate From 2010 to 2014, Alborz and Qazvin provinces had the highest mortality rate, respectively (4.50, 95% CI: 3.29–5.49), (4.20, 95% CI: 2.21–5.27), and Markazi and Kermanshah provinces were next in rank (4.01, 95% CI: 2.56–5.25), (3.89, 95% CI: 2.89–4.77) (Fig. 8.a). Also, from 2015 to 2019, the provinces of Alborz and Qazvin remained in the very

a: Average age-standardized incidence rate due to falls per 100,000 individuals in male in Iran provinces between 2010-2014



b: Average age-standardized incidence rate due to falls per 100,000 individuals in male in Iran provinces between 2014-2015



c: Average age-standardized incidence rate due to falls per 100,000 individuals in male in Iran provinces over 10 years

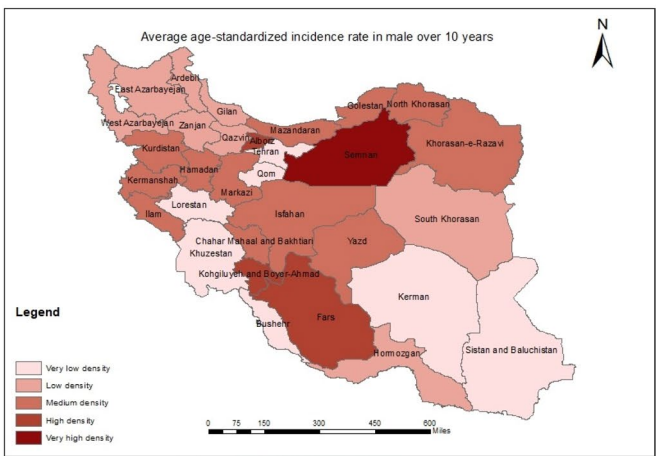
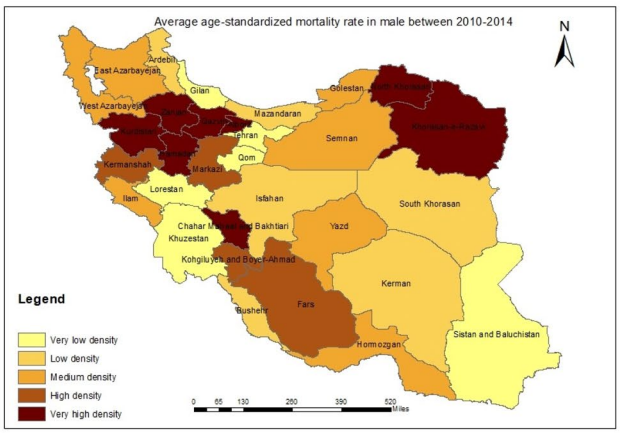
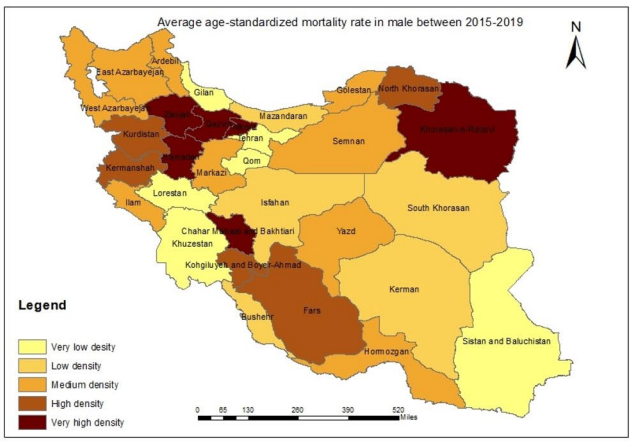


Fig. 5 **a** Average age-standardized incidence rate due to falls per 100,000 individuals in male in provinces of Iran between 2010-2014. **b** Average age-standardized incidence rate due to falls per 100,000 individuals in male in provinces of Iran between 2014-2015. **c** Average age-standardized incidence rate due to falls per 100,000 individuals in male in provinces of Iran over 10 years

a: Average age-standardized mortality rate due to falls per 100,000 individuals in male sexes in Iran provinces between 2010-2014



b: Average age-standardized mortality rate due to falls per 100,000 individuals in male sexes in Iran provinces between 2015-2019



c: Average age-standardized mortality rate due to falls per 100,000 individuals in male sexes in Iran provinces over 10 years

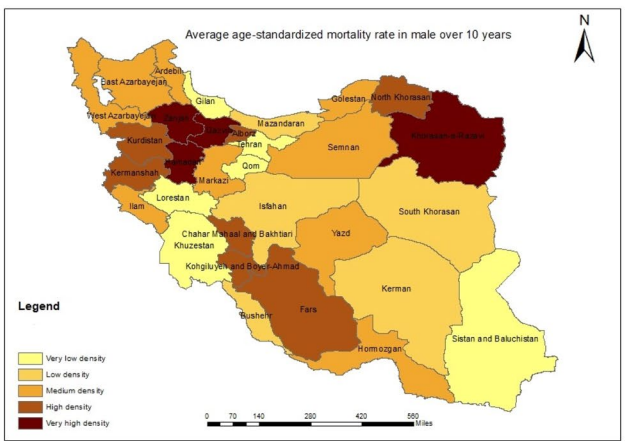
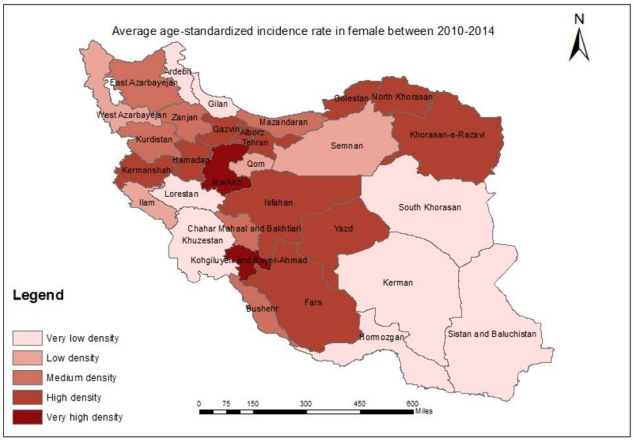
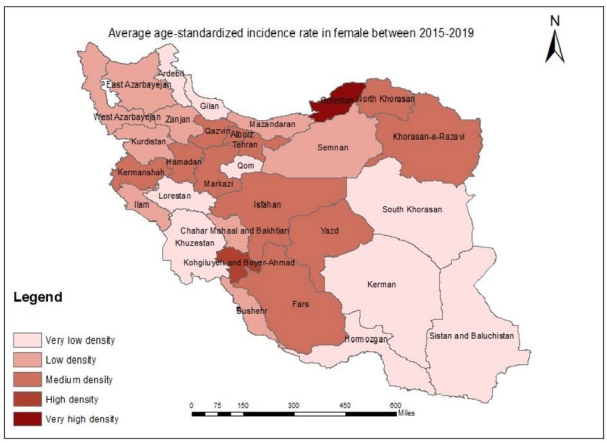


Fig. 6 **a** Average age-standardized mortality rate due to falls per 100,000 individuals in male in provinces of Iran between 2010-2014. **b** Average age-standardized mortality rate due to falls per 100,000 individuals in male in provinces of Iran between 2015-2019. **c** Average age-standardized mortality rate due to falls per 100,000 individuals in male in provinces of Iran over 10 years

a: Average age-standardized incidence rate due to falls per 100,000 individuals in female in Iran provinces between 2010-2014



b: Average age-standardized incidence rate due to falls per 100,000 individuals in female in Iran provinces between 2015-2019



c: Average age-standardized incidence rate due to falls per 100,000 individuals in female in Iran provinces over 10 years

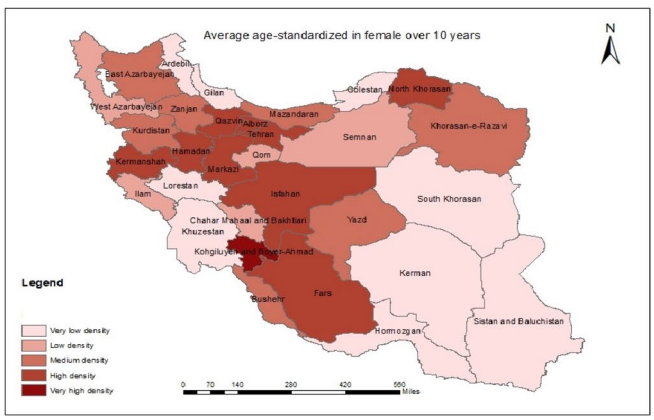
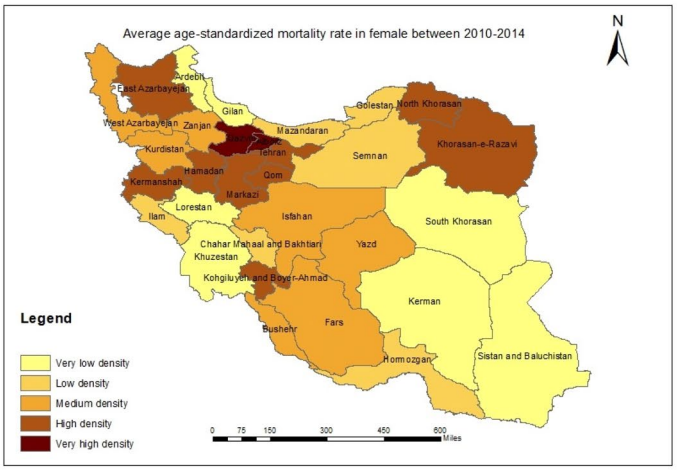
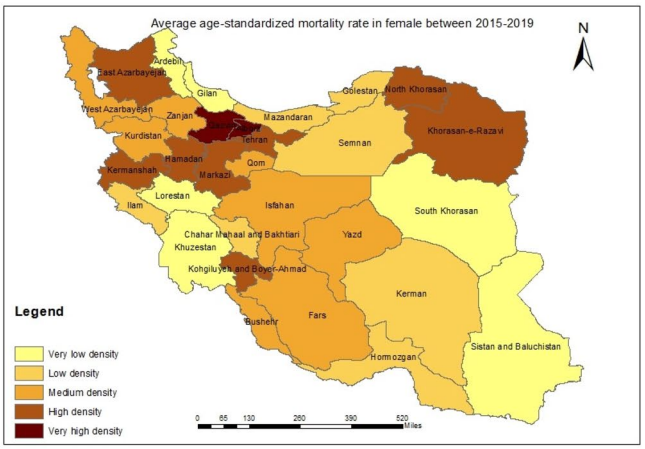


Fig. 7 **a** Average age-standardized incidence rate due to falls per 100,000 individuals in female in provinces of Iran between 2010-2014. **b** Average age-standardized incidence rate due to falls per 100,000 individuals in female in provinces of Iran between 2015-2019. **c** Average age-standardized incidence rate due to falls per 100,000 individuals in female in provinces of Iran over 10 years

a: Average age-standardized mortality rate due to falls per 100,000 individuals in female sexes in Iran provinces between 2010-2014



b: Average age-standardized mortality rate due to falls per 100,000 individuals in female sexes in Iran provinces between 2015-2019



c: Average age-standardized mortality rate due to falls per 100,000 individuals in female sexes in Iran provinces over 10 years

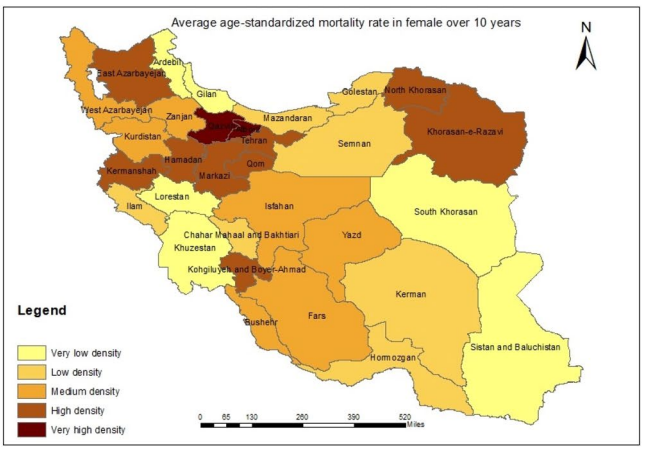


Fig. 8 **a** Average age-standardized mortality rate due to falls per 100,000 individuals in female in provinces of Iran between 2010-2014. **b**: Average age-standardized mortality rate due to falls per 100,000 individuals in female in provinces of Iran between 2015-2019. **c**: Average age-standardized mortality rate due to falls per 100,000 individuals in female in provinces of Iran over 10 years

high density group (4.30, 95% CI: 3.12–5.36), (4.02, 95% CI: 2.13–5.14), and the provinces of North Khorasan and Markazi remained in the high density group, respectively (3.69, 95% CI: 2.65–4.52), (3.63, 95% CI: 2.25–4.91) (Fig. 8.b). Over the past ten years, Alborz and Qazvin provinces have had the highest rates (4.40, 95% CI: 3.21–5.42) (4.11, 95% CI: 2.17–5.20), followed by Markazi and North Khorasan provinces, respectively (3.82, 95% CI: 2.40–5.08), (3.78, 95% CI: 2.67–4.59) (Table 3, Fig. 8.c).

Hot spots

Based on the results of the Hot Spot analysis for the age-standardized incidence rate of falls in both sexes, in the five-year period from 2010 to 2014, Fars province showed the highest incidence rate compared to the national average (P<0.05). Yazd and Lorestan provinces are in the next ranks (*P*<0.01). Sistan and Baluchestan and Kerman regions have a lower rank compared to the national average (Fig. 9). In the period from 2015 to 2019, the results are similar to the first half (Fig. 10).

The results of the Age-standardized mortality rate from 2010 to 2014 show that Kurdistan and Kermanshah provinces are higher than the national average (*P*<0.01) (Fig. 11). However, from 2015 to 2019, only Kermanshah province was ranked higher (P<0.01), and Sistan and Baluchistan provinces were lower than the national average (*P*<0.01) (Fig. 12).

Discussion

Our study showed that between 2010 and 2019, age-standardized incidence and mortality rates decreased in both sexes. According to A Global Report on Falls Prevention Epidemiology of Falls, incidence rates decreased by 28 to 35 percent among people over 64, and increasing age is a significant risk factor for fatal falls. Overall, mortality rates are higher in men than in women across all age groups. This may be due to men being more physically active and engaging in risky behaviors [21]. In line with this, our findings showed that age-standardized incidence and mortality rates were almost double in men compared to women over the ten years. Our results are homogeneous and include global patterns of fall-related injuries. In Iran, inequalities in environmental conditions, access to health care, and socioeconomic factors are the causes of differences in fall incidence and mortality rates across regions. Inquisitive about this aging urgency in other countries with diverse geographic and socioeconomic landscapes also confirms the influence of these factors on Health indicators of falls. For example,

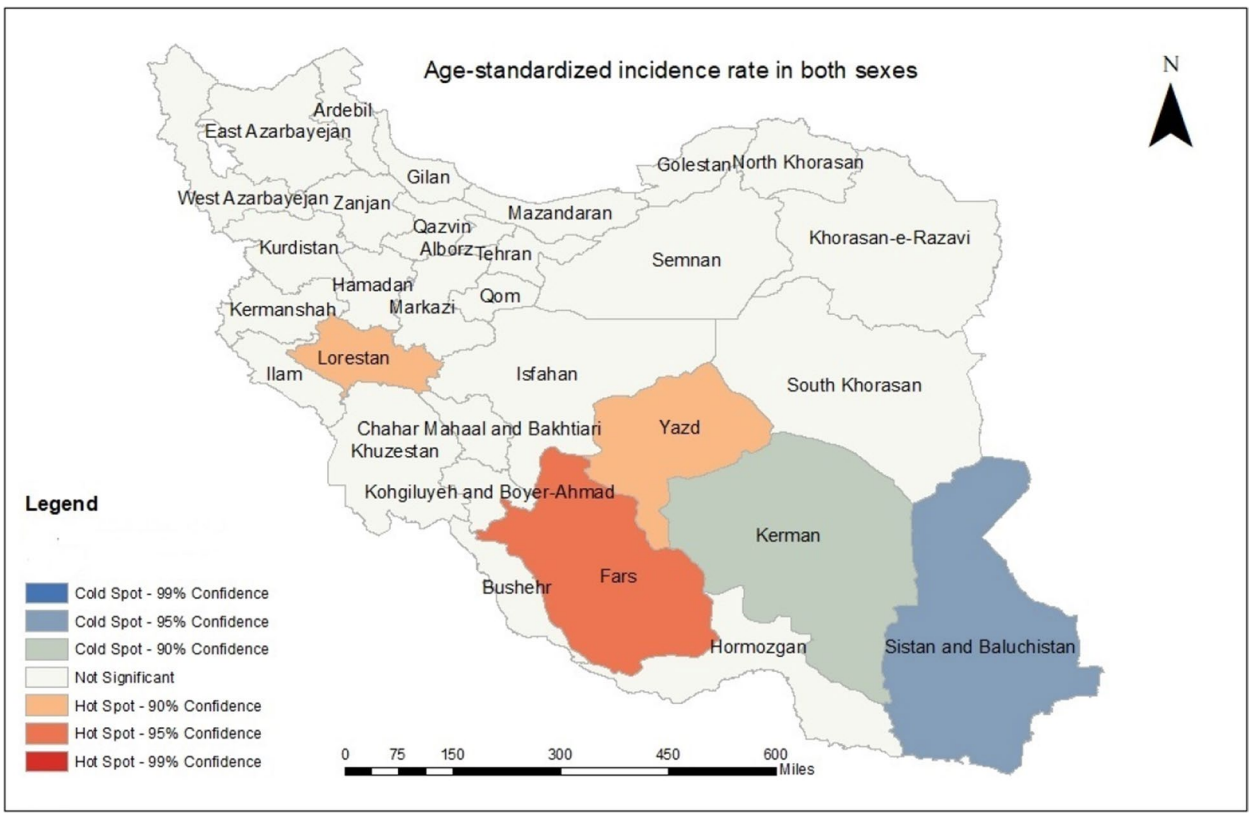


Fig. 9 Hotspot map of the Age-standardized incidence rate due to falls in provinces of Iran 2010-2014

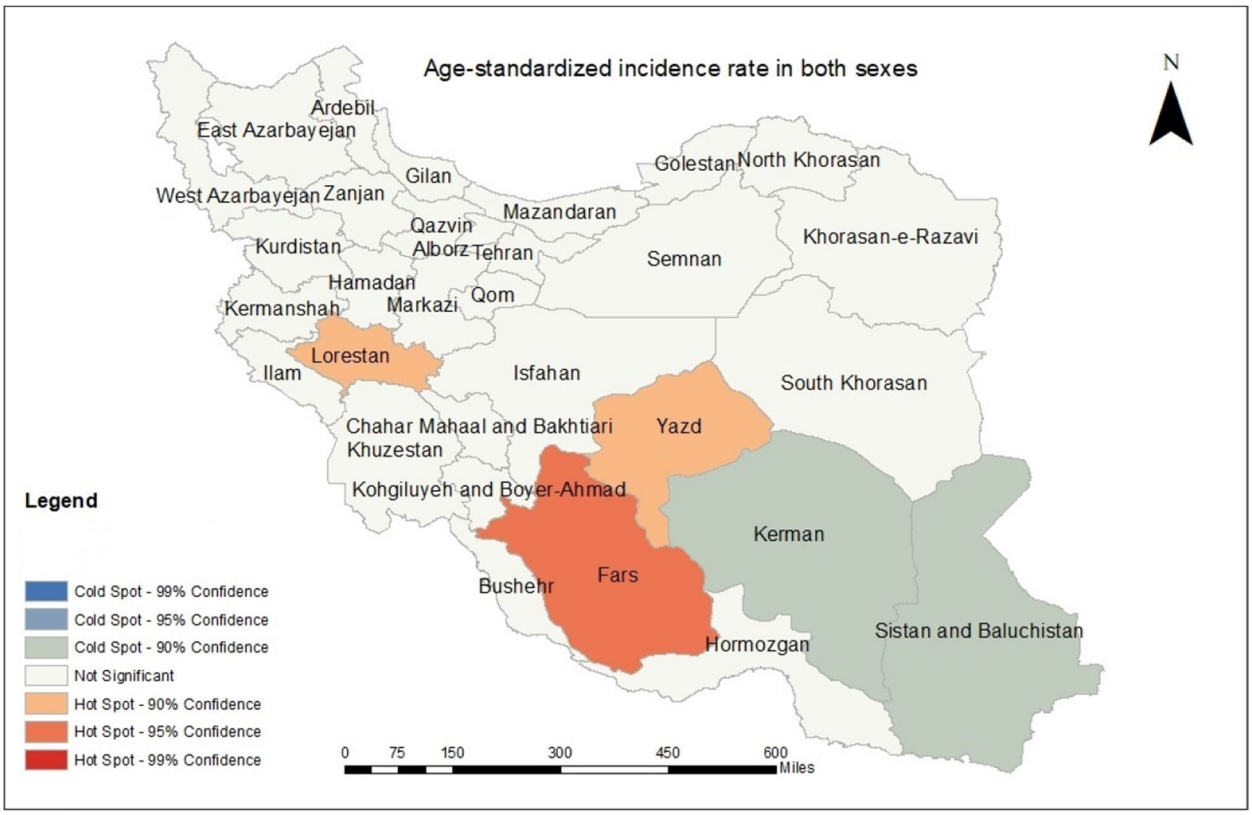


Fig. 10 Hotspot map of the Age-standardized incidence rate due to falls in provinces of Iran 2015-2019

studies from China have shown that injury rates in different regions are often influenced by local economic development and other infrastructure conditions [22, 23].

J.A. Haagsm et al. examined trends in mortality from falls in 22 European Union countries and found that mortality rates and the incidence of fall-related injuries requiring healthcare varied across regions. The lowest rates were reported in Greece and Portugal and the highest in Norway and Belgium [24]. A report on falls-related mortality among adults aged 75 years or older in the United States, 2000–2016, by K.A. Hartholt, showed that the crude mortality rate increased from 51.6 per 100,000 to 122.2 per 100,000. Furthermore, the annual percentage change was 1.5 for the age group 75 years and older and increased with age from 3.5% to 6.4% in adults 75–79 years [25]. The trend of falls-related mortality among the elderly in Brazil, based on a time series from 2008 to 2016, showed that the trend of falls-related mortality was present in all age groups, with the highest rate in the age group 65 years and older (31.2%) [26]. Complementing the above findings, S. Kim et al., using global time series modeling and analysis using mortality data from the World Health Organization database, showed that the trend of falls-related mortality decreased from 1990 to 2009. However, it increased in 2021. Furthermore, this rate is projected to grow significantly in middle- and high-income countries by 2040, especially among women and people over 85 [27].

In contrast to the above findings and consistent with our results, a national survey by Z. Ghodsi et al. showed that the age-standardized mortality rate due to falls per 100,000 population decreased from 2.61 in 1990 to 2.13 in 2015. Males are also at higher risk of death from falls than females [14]. A 16-year study of the mortality trend from falls in Fars province by H. Azarbakhsh et al. indicated that the mortality rate in males was stable but increasing in females in this province [28]. At the same time, our study did not identify Fars as a hot spot regarding the average age-standardized mortality rate. It ranked ninth in mortality in both sexes and eighth and thirteenth in men and women, respectively. In addition, the study added that the total years of life lost due to falls in males was 25,437, and in females, 5,720 years, and this rate is decreasing in males, but it is constant in women [28]. Our findings indicated that this province is a hot spot regarding average incidence. Also, Fars ranked first in men, second in both sexes, and fifth in women in average 10-year incidence.

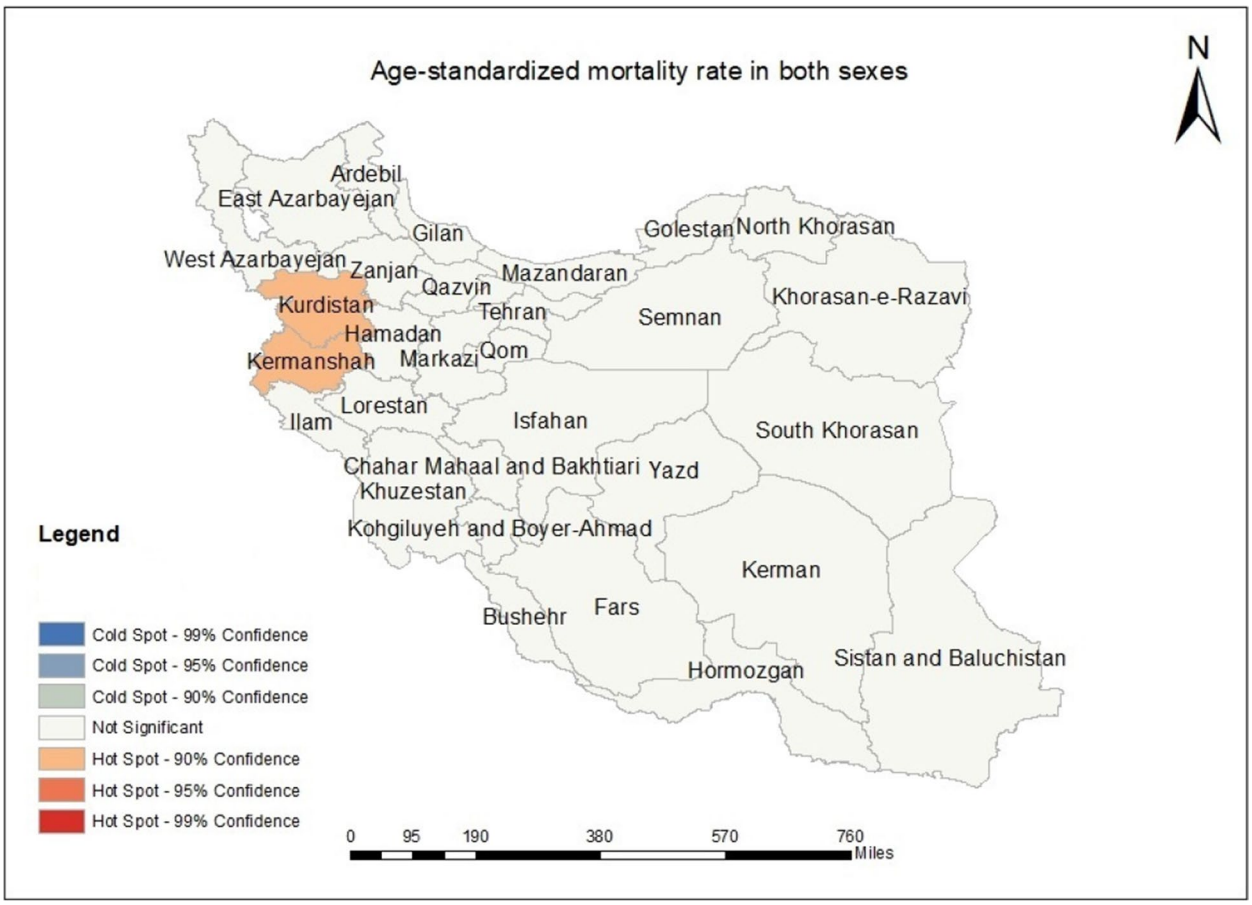


Fig. 11 Hotspot map of the Age-standardized mortality rate due to falls in provinces of Iran 2010-2014

Our results showed that Qazvin province in the northwest has the highest incidence rate in both sexes and males and for females, Alborz province, which is also located in the northwest, ranks first in incidence. The spatial distribution of 10-year mortality rates in the study by M. Heydari showed that the southwest, center, and east regions have lower mortality rates [29]. In line with the present study, Khuzestan province, located in southwest Iran, has the lowest age-standardized mortality rate over 10 years in both sexes and by sex. A study of the mortality trend from falls at the provincial level in Iran from 1990 to 2015 showed that Zanjan had the highest decreasing trend in both sexes, followed by Tehran among females and Lorestan among males [14]. According to our study, the average age-standardized mortality rate from 2010 to 2019 in Zanjan among 31 provinces ranked sixth in both sexes, Tehran ranked eighth in females, and Lorestan ranked twenty-seventh. In addition, Fars had the highest rate in females, Hormozgan, and Isfahan in males between 1990 and 2015 [14]. In the present study, Fars ranked thirteenth in females, and Hormozgan and Isfahan ranked fourteenth and twenty-fourth in males, respectively. These differences could indicate an improvement in the health of older people during this period.

According to the study by N'Imani et al., the prevalence rate among the Iranian elderly is 25.5% [1]. The prevalence rate of falls in older adults in Bojnourd city in North Khorasan was estimated to be 30% [30]. Based on the present findings, this province's average age-standardized incidence rate is eighth in both sexes and tenth and third in males and females, respectively. Also, the prevalence rate of this common condition in older people was reported to be 82.31% in Charm City, Kohgiluyeh and Boyer-Ahmad Province [31]. In line with the present study, this province, located in the southwest, had the highest incidence rate over ten years in both sexes and females, and Fars province, which is also located in the southwest, had the highest incidence rate in males. In addition, this rate in Babol in northern Iran was reportedly 35.1% [32]. In our study, Gilan, in the north of the region, had the lowest average incidence rate for females over ten years compared to other provinces.

Meanwhile, Bushehr province in the southwest and Sistan and Baluchistan provinces in the southeast have

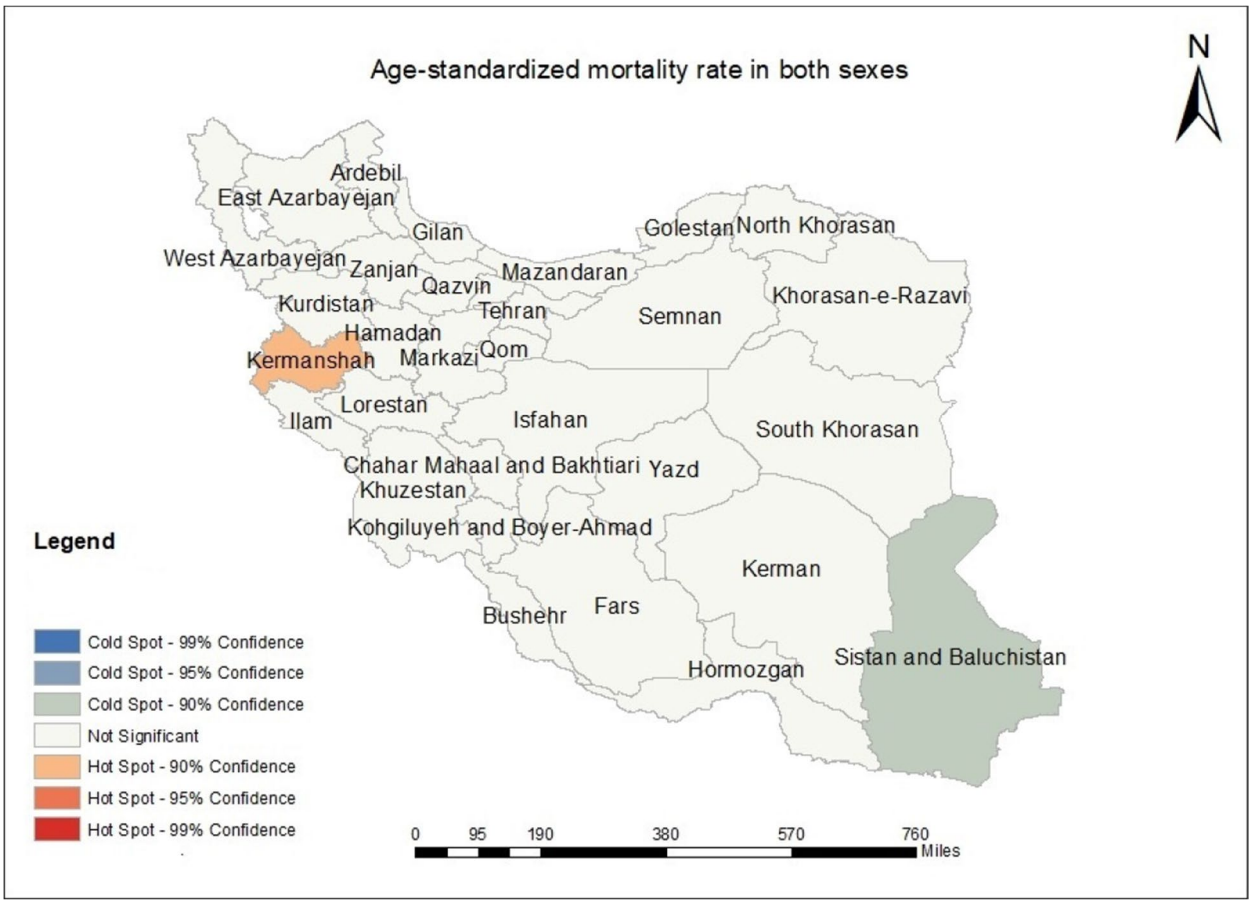


Fig. 12 Hotspot map of the Age-standardized mortality rate due to falls in provinces of Iran 2015-2019

the lowest incidence rates for both sexes and males, respectively. Based on a four-year cohort, the incidence rates in Kashan city in Isfahan province and Khorramabad in Lorestan province were 31.9% and 24.8%, respectively [33, 34]. Our results indicated that the average age-standardized incidence rates at 10 years in Isfahan and Khorramabad provinces were ranked seventh and twenty-ninth in both sexes, respectively.

Global, regional, and national estimates of morbidity and mortality from the Global Burden of Disease Study using GBD data showed that in 2017, the incidence of falls decreased by 3.7% from 1990 to 2017, and the age-standardized mortality rate was estimated at 9.2 per 100,000 people in 2017. Overall, the findings indicate a significant burden of falls [35]. Consistent with this finding, although our studies show a decrease in age-standardized incidence and mortality, the consequences of falls cannot be ignored, especially considering the changes in the age pyramid. The European Union Population Report in 2023 showed that 65 years and older accounted for 21.3% of the population. While in 2024, these changes increased to 21.6% [36]. In Iran, declining fertility rates, mortality rates, and increasing life expectancy have caused the population to age in the past three decades. According to the article by Mehri et al., Iran is the second country in terms of the growth rate of the population 60 years and older. It is also predicted that by 2050, people aged 60 and older (31%), 65 years and older (22%), and the 80 years and older group (3.8%) [37].

Globally, 684,000 people die each year from falls, with over 80% occurring in low- and middle-income countries [38]. A review in the Middle East and North Africa reported that 17.6% of older adults experience at least one fall. Falls, mental health problems such as fear of falling, anxiety, and depression are some of the common consequences of falls [39]. Pengpeng Ye et al., examining the burden of falls among people aged 60 years and older in China, found that 1238.9 DALYs per 100,000 people were due to falls, and there was no significant relationship between gender and the burden of falls. However, the mortality rate and DALYs from falls were significantly higher in the age group 80 years and older than in other

age groups [23]. GBD 2019 data show that the mortality rate and DALYs from falls in people aged 60 years and older with low bone density increased from 1990 to 2019 in China, with an average annual change of 1.74% [40]. A comparison with the Global Burden of Disease Study indicates that Iran's fall-related injuries are part of a broader global trend, where falls remain a leading cause of injury and disability among the elderly[35, 41]. Furthermore, studies have shown that the burden of falls is lower in high-income countries than in middle-income countries due to the lack of necessary infrastructure in society for the aging population [35].

Our results also suggest that targeted interventions considering regional health inequalities may be needed to reduce the burden of falls, particularly in the focal areas identified by spatial analysis. The growth of the world's aging population poses significant challenges to healthcare systems. The global proportion of people aged 60 and older is projected to increase dramatically by 2050 [42]. Demographic changes will inevitably increase fall-related injuries. Therefore, preventive measures are needed, especially in high-risk areas such as Qazvin and Fars provinces. Interventions such as physiotherapy, home modifications, and public health education and their adaptation to local and cultural contexts effectively reduce this health issue. A systematic review aimed at preventing falls in the elderly showed that vitamin D intake reduces the risk of falls by seventy percent. In addition, exercise and walking are especially effective for the elderly in care centers [43].

In addition, regions in Iran with poorer socioeconomic development and housing conditions report higher rates of falls. Global patterns, consistent with our study, show that falls are more common in older adults with lower incomes, suggesting the critical role of social determinants of health [22]. A review of the cost-effectiveness of fall prevention services showed that the cost of preventing falls per person ranges from $272 to $880, and visits, medical consultations, and education of the target population were the most significant percentage of interventions. Also, although highly effective, the combination of these interventions is costly. Therefore, it is recommended that each country provide low-cost and highly effective services in proportion to the available resources [44]. According to the results of M. YILMAZ et al., fall prevention programs reduce health system costs [45]. Targeted group and individual physical activity, cataract surgery, pacemakers, vitamin D, Tai chi exercises, and reducing risk factors and places at home effectively prevent falls and their consequences [46]. Therefore, prioritizing planning and access to elder care services can significantly reduce these inequalities.

Conclusion

The fall trend in Iran was comprehensively assessed during 2010-2019. Fars, Qazvin, and Kermanshah provinces were identified as the epicenters of fall-related injuries. Overall, the age-standardized mortality rate of falls decreases, but its age-standardized incidence rate, especially in socioeconomically deprived areas. Consequently, socioeconomic status and the level of access to elderly care be considered in health-treatment planning.

The aging of the Iranian population is an urgent public health challenge, so multifaceted fall prevention programs play a significant role in reducing the burden of health-related injuries. Policymakers need to consider regional inequalities and access to health care when implementing geriatric care.

Conducting studies and using their results to identify factors affecting inequality in access to health services is recommended to increase the effectiveness of elder-care programs and reduce the impact of falls on the target population.

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Authors' contributions

Author Contributions •Fatemeh Majdolashrafi: Conceptualized the study, contributed to data collection and analysis, and drafted sections of the manuscript. •Ali Delpisheh: Supervised the project, provided critical revisions, and ensured the methodological rigor of the study. •Aram Halimi: Conducted data collection and analysis, interpreted the findings, and contributed to manuscript preparation. •Haniyeh Yeganeh: Contributed to drafting and editing the manuscript, and provided administrative support. •Goljamal Jorjani: Conducted data collection and analysis, literature review, and manuscript formatting. •Mohammad Hossein Panahi: Coordinated the study, ensured alignment with ethical and methodological standards, and served as the corresponding author.

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Data availability

The datasets presented in this study can be found at: https://vizhub.healthdata.org/gbd-results/.

Declarations

Ethics approval and consent to participate

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences under the code IR.SBMU.PHNS.REC.1403.077.

Consent for publication

Not applicable.

Competing interests
The authors declare no competing interests.

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