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The national and provincial burden of transport injuries in Iran between 1990 and 2021

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Transport injuries (TIs) are a major cause of mortality and morbidity worldwide, and Iran, with its rapid demographic transitions in recent decades, is no exception. This study aimed to assess the burden of TIs in Iran and its provinces from 1990 to 2021. Estimates from the Global Burden of Diseases (GBD) 2021 were used to report age-standardized rates (ASRs) for the prevalence, incidence, mortality, and disability-adjusted life years (DALYs) of TIs by sex, age group, injury type, province, and Socio-demographic Index (SDI). In 2021, Iran recorded 1.147 million (95% uncertainty interval (UI): 1.014 to 1.287 million) incident cases of TIs with an age-standardized incident rate of 1341.9 per 100,000 (95% UI: 1193.7 to 1495.1). Compared with 1990, its prevalence, incidence, death, and DALY rates decreased by − 52% (95% UI: − 54% to − 50%), − 52% (95% UI: − 55% to − 50%), − 62% (95% UI: − 65% to − 58%), and − 64% (95% UI: − 67% to − 61%), respectively. At the provincial level, Tehran (233.1; 95% UI: 191.3 to 304) had the lowest age-standardized DALY rate, while the highest DALY rate was for Sistan-Baluchistan (2155.3; 95% UI: 1866.2 to 2478.3). In addition, age-standardized DALY rates were mainly higher for males, the 20–24 age group, and provinces with a lower SDI. Despite a significant decrease in TIs in Iran since 1990, they still pose a significant burden, with notable disparities across provinces and demographic groups. Targeted prevention programs focusing on high-risk populations, such as young adults and lower-SDI provinces with lower SDI, are recommended.

Keywords Transport injury, Global burden of disease, Iran, Epidemiology

Transport injuries (TIs) are among the major causes of mortality and morbidity worldwide, accounting for approximately 50 million injuries and 1.35 million fatalities annually[1]. In Iran, TIs are reported as the third most common cause of death, with 21,122 deaths per year[2]. Furthermore, transport injuries place a significant strain on the healthcare system and economy, consuming substantial resources[3].

The burden of TIs varies significantly across regions, countries, and even provinces. This was confirmed by Sadeghian et al., who found a significant disparity in the burden of TIs across provinces in Iran. Notably, Fars and Sistan-Baluchestan, two southern and eastern provinces, had the smallest decrease in the burden of TIs, despite an overall decline since 1990 in Iran[2]. Factors such as road infrastructure, traffic law enforcement, and demographic conditions can contribute to these differences. While data on these factors at the provincial level is limited, province-specific TIs estimates would provide a clearer understanding of their impact, helping plan targeted policy interventions.

Furthermore, the impact of TIs differs among various age and gender groups. For instance, males, particularly young adults, tend to engage in risk-taking behaviors such as speeding, reckless driving, and lower compliance with traffic laws. They are also more likely to be involved in crashes due to their inexperience and different risk perceptions compared to older age groups[4]. Given the identified disparities, adopting age and gender targeted approaches would be beneficial in the context of transport injuries. The Graduated Driver Licensing (GDL) program is one such targeted intervention. GDL implements a three-phase system to obtain a full driving license and focuses on supervised learning phases, especially for adolescents. A systematic review by Peden et al., reported effectiveness of GDL in reducing motor-vehicle-related injuries and fatalities for adolescent[5].

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Additionally, one study found a 59% reduction ($p < 0.001$) in the rate of fatal motor vehicle crashes in 14- to 18-year-olds after implementing GDL, whereas the reduction was not significant for adults aged 19 years and older[6]. Considering the importance of targeted approaches, identifying vulnarbale age and gender groups, such as young adults, can aid in more evidence-based decision-making.

Despite a significant decrease in its burden in recent decades, TIs remain a major health concern in Iran. As reported in a previous study, in 1990, TIs ranked as the sixth cause of disability-adjusted life years (DALYs) among all causes in males. However, in 2015, it ascended to second place, following cardiovascular diseases[7]. To address this issue, it is necessary to implement comprehensive, evidence-based intervention programs.

The present study aimed to update prior research by using the latest Global Burden of Disease (GBD) data. It focuses on identifying patterns characteristic of different age and gender groups in terms of the burdon of TIs. Additionally, it reports estimates for provinces with a high burden in Iran, particularly those with persistently high burdens and minimal improvement over time.

The Institute of Health Metrics and Evaluation (IHME) provides information on prevalence, incidence, DALY, and mortality rates through Global Burden of Disease (GBD) research[8]. In this study, GBD 2021 data will be applied to assess the burden of TIs in Iran according to different age and gender groups, injury type and sociodemographic index (SDI). It will also provide estimates for global and Middle East and North Africa (MENA), as well as province-specific data for Iran.

Methods

Data sources

GBD studies are presented by the Institute of Health Metrics and Evaluation (IHME) and are used to determine epidemiological trends in injuries, non-communicable illnesses, and communicable diseases worldwide[9]. The most recent available GBD study (GBD 2021) provides data on 369 diseases and injuries and 87 risk factors according to age and sex groups in 204 countries. It also provides estimates at national and provincial levels for 21 countries, including Iran[10]. The GBD hierarchy classifies TIs as level 2 conditions, which fall under the category of injuries as level 1. These conditions include road injuries (divided into motorized vehicles with three or more wheels (motor vehicle) road injuries, cyclist road injuries, motorcyclist road injuries, pedestrian road injuries, and other road injuries) and other transport injuries[2].

The prevalence, incidence, mortality, and DALYs per 100,000 population were evaluated in this study using GBD 2021. The Global Health Data Exchange (GHDx) and the GBD results tools provided online access to the data. The data modeling and estimation framework of GBD 2021 has been explained in prior studies. It is the same as previous GBD projects, along with corrections for miscoding and misclassification[11]. According to the IHME, sources such as Iran's Demographic and Health Survey, the national forensic medicine system, hospital data samples, and the national death registration system were used to provide data for GBD 2021 and TIs in Iran[10].

Statistical analysis

Estimates were obtained from the GBD 2021 study, which calculated rates by dividing the population into age groups and applying age-standardization adjustment. The GBD 2021 study provides age-standardized rates (ASRs) using the GBD world standard population. Employing ASRs enables reliable comparison across locations with different demographic structures. In contrast to raw rates, ASRs adjust for age distribution, ensuring that differences in injury burden are not solely due to variations in population age structure (12).

To ensure consistency across age and sex groups while accounting for missing data and varying injury severities, the DisMod-MR 2.1 tool, a Bayesian meta-regression model, was used, along with the Cause of Death Ensemble Model (CODEm) to provide the results of mortality calculations[8].

Years Lived with Disability (YLDs) represent years of life lived in poor health or with a disability due to a specific injury or condition. They are calculated by combining the number of incident cases, disability weight (reflecting the severity of health loss), and average duration of the condition. GBD studies employ the GBD Disability Weight Survey to provide the values for these calculation. Years of Life Lost (YLLs) are computed by multiplying the number of deaths by the years of life lost due to injury, based on standard life expectancy table at the age of death. To compute the DALYs as an overall indicator of Burden of TIs in terms of fatal and nonfatal injuries, the number of YLDs and YLLs were added together[12,13]. In the present study, after obtaining YLD, YLL, and DALY values from the GBD 2021 database, these estimates were extracted at the national and provincial levels to compare variations in the burden of TIs across Iran.

To analyze the relationship of the SDI and the DALYs caused by TIs, Smoothing splines models were employed. This method can be used to identify possible non-linear correlations between SDI and DALY rates[10]. SDI values range from 0 to 1 and indicate a composite of factors, including income per capita, education level, and underage fertility. The values provided by the GBD study for each province were utilized to perform the analysis[10]. Expected DALY rates based on the SDI are presented, along with the observed rates for 31 provinces of Iran.

The results are reported for Iran (national and provincial), the global, and MENA regions. Estimates for the MENA region were included to provide a broader view of Iran's regional status concerning the burden of TIs, potentially aiding in identifying regional trends, shared risk factors, and possible intervention strategies that could be adapted to Iran. The MENA region, as defined by the GBD, includes 21 countries: Tunisia, Iraq, Algeria, Qatar, Libya, Jordan, Yemen, Saudi Arabia, Afghanistan, Oman, Bahrain, Egypt, Morocco, Lebanon, Iran, the Syrian Arab Republic, Sudan, the United Arab Emirates, Turkey, and Palestine[14].

An uncertainty interval (UI) of 95% was used for all estimates in this study. Uncertainty was calculated by 1000 draws sampled at each computational step obtained through several sources, such as input data, residual non-sampling error estimates, and measurement error corrections. The UIs are presented as the 25th and 975th

values of the ordered draws. The R statistical program (version 3.6.1, R Foundation for Statistical Computing, Vienna, Austria) was used for all statistical analyses.

Results

National level

In 2021, there were 3.083 million (95% UI: 2.847 to 3.34 million) prevalent cases of TIs in Iran with an age-standardized prevalence rate of 3419.9 per 100,000 (95% UI: 3172.3 to 3687.6). Compared with 1990, the age-standardized prevalence rate of TIs in Iran decreased by − 52% (95% UI: − 54% to − 50%) (Table 1 and Supplementary Table 1, Additional File 1). There were also 1.147 million (95% UI: 1.014 to 1.287 million) incident cases and an age-standardized incidence rate of 1341.9 per 100,000 (95% UI: 1193.7 to 1495.1), which has dropped by − 52% (95% UI: − 55% to − 50%) since 1990 (Table 1 and Supplementary Table 2, Additional File 1). Deaths and death rates were 19,472.6 (95% UI: 18,326.1 to 20,868.6) and 22.64 per 100,000 (95% UI: 21.29 to 24.3), respectively, with a percentage change of − 62% (95% UI: − 65% to − 58%), compared with the 1990 death rate (Table 1 and Supplementary Table 3, Additional File 1). Furthermore, DALY and DALY rates were 1.123 million (95% UI: 1.043 to 1.202 million) and 1283.4 per 100,000 (95% UI: 1193.7 to 1371.3) with a percentage change of − 64% (95% UI: − 67% to − 61%), lower than 1990's DALY rate (Table 1 and Supplementary Table 4, Additional File 1). In comparison to the global and MENA regions, Iran had higher prevalence, incidence, and DALY rates of TI cases in 2021. However, between 1990 and 2021, Iran showed a more noticeable decline in the mentioned estimates (Figs. 1 and 2).

Subnational level

In 2021, Tehran (290,505.65; 95% UI: 270,764 to 313,282), Fars (269,254; 95% UI: 247,178 to 292,906), and Khorasan-e-Razavi (246,127; 95% UI: 227,397 to 266,061) had the highest prevalence of TI cases. In contrast, the lowest prevalence of TI cases was reported in Ilam (24,439; 95% UI: 22,568 to 26,540), Semnan (29,151; 95% UI: 27,081 to 31,611), and South Khorasan (31,062; 95% UI: 28,702 to 33,424). Also, in 2021, the highest age-standardized prevalence rates of TI cases per 100,000 population were found in Fars (4843.9; 95% UI: 4473.6 to 5237.3), Kohgiluyeh and Boyer-Ahmad (4394.8; 95% UI: 4028.3 to 4806.9), and Mazandaran (4278.1; 95% UI: 3956.4 to 4642.9), while the lowest prevalence rates were for Tehran (1774.8; 95% UI: 1660.8 to 1907.3), Qom (2379.2; 95% UI: 2214.7 to 2553.1), and Ardebil (3008.3; 95% UI: 2814 to 3238.7) (Fig. 1A; Table 1). The sex-specific prevalence rates of TI cases in 2021 are shown in Fig. 1A. In every province, men had a higher age-standardized prevalence rate of TI cases than women.

Compared with 1990, Qom (− 64%; 95% UI: − 65 to − 63%), Zanjan (− 59%; 95% UI: − 61 to − 57%), and Ardebil (− 59%; 95% UI: − 60 to − 57%) had the greatest reductions and percentage changes of age-standardized prevalence rates in TI cases per 100,000 by the year 2021. Mazandaran (− 43%; 95% UI: − 45 to − 41%), Sistan-Baluchistan (− 43%; 95% UI: − 46 to − 40%), and Fars (− 44%; 95% UI: − 45 to − 42%) had the smallest reduction of prevalence rates (Fig. 2A; Table 1). As represented in Fig. 2A, reductions in age-standardized prevalence rates of TI cases were greater among females than males across all provinces.

Moreover, Fars (1907.7; 95% UI: 1694.6 to 2136.9), Kohgiluyeh and Boyer-Ahmad (1719.6; 95% UI: 1510.7 to 1945.1), and Mazandaran (1693.4; 95% UI: 1494.7 to 1903.6) were reported to have the highest age-standardized incidence rates of TI cases per 100,000 in 2021. However, the lowest incidence rates of TI cases were for Tehran (663.8; 95% UI: 592.9 to 746.5), Qom (905.6; 95% UI: 807.8 to 1019.6), and Ardebil (1180.5; 95% UI: 1046.9 to 1323.1) (Fig. 1B; Table 1). The sex-specific incidence rates of TI cases in 2021 are depicted in Fig. 1B. As shown, in every province, men had a higher age-standardized incidence rate of TI than women, similar to the prevalence rates.

Between 1990 and 2021, Qom (− 64%; 95% UI: − 66 to − 62%), Zanjan (− 61%; 95% UI: − 63 to − 58%), and Ardebil (− 58%; 95% UI: − 61 to − 55%) were reported to have the greatest reduction in age-standardized incidence rates in TI cases per 100,000 population. In contrast, Sistan-Baluchistan (− 43%; 95% UI: − 47% to − 39%), Mazandaran (− 43%; 95% UI: − 46% to − 39%), and Fars (− 44%; 95% UI: − 48 to − 40%) had the smallest reduction in incidence rates (Fig. 2B; Table 1). As presented in Fig. 2B, reductions in age-standardized incident rates in TI cases were greater among females than among males across all provinces.

Sistan-Baluchistan (38.2; 95% UI: 32.7 to 45), Fars (38; 95% UI: 32.1 to 44.6), and Kerman (33.5; 95% UI: 28.7 to 38.8) had the highest age-standardized death rates of TI cases per 100,000 in 2021. In contrast, the lowest death rates were observed in Tehran 3.1 (2.5, 4.7), Qom 12.4 (10.4, 15.6), and Alborz (15.1; 95% UI: 12.6 to 18.3) (Fig. 1C; Table 1). The sex-specific incident rates of TI cases in 2021 are depicted in Fig. 1C. Although the disparity in death rates between males and females in Tehran was minimal, the death rate of TI cases was higher among males than females across all provinces.

Compared with 1990, Qom (− 71%; 95% UI: − 77 to − 62%), Markazi (− 68%; 95% UI: − 75 to − 61%), and Kurdistan (− 68%; 95% UI: − 75 to − 60%) had the greatest reductions and percentage changes of death rates in TI cases per 100,000 in 2021. Mazandaran (− 49%; 95% UI: − 60 to − 35%), Khuzestan (− 51%; 95% UI: − 60 to − 39%), and Fars (− 53%; 95% UI: − 64 to − 41%) were found to have the smallest reduction in death rates (Fig. 2C; Table 1).

Also, Sistan-Baluchistan (2155.3; 95% UI: 1866.2 to 2478.3), Fars (2115.9; 95% UI: 1826 to 2420.6), and Hormozgan (1861.5; 95% UI: 1586.4 to 2135.2) had the highest age-standardized DALY rates of TI cases per 100,000 in 2021. In contrast, the lowest DALY rates of TI cases were reported in Tehran (233.1; 95% UI: 191.3 to 304), Qom (691.4; 95% UI: 585.9 to 853.1), and Alborz (860.8; 95% UI: 733.9 to 1005.8) (Fig. 1D; Table 1). The sex-specific incidence rates of TI cases in 2021 are depicted in Fig. 1D. Males had a higher age-standardized DALY due to TIs than females across all provinces except for Tehran, where the disparity was smaller.

Since 1990, Qom (− 73%; 95% UI: − 78 to − 66%), Zanjan (− 72%; 95% UI: − 77 to − 65%), and Kurdistan (− 71%; 95% UI: − 76 to − 66%) have been found to have the greatest reduction in DALY rates in TI cases per

	Prevalence (95% UI)			Incidence (95% UI)			Death (95% UI)			DALYs (95% UI)		
	Counts (2021)	ASRs per 100,000 (2021)	Pcs in ASR 1990–2021	Counts (2021)	ASRs per 100,000 (2021)	Pcs in ASR 1990–2021	Counts (2021)	ASRs per 100,000 (2021)	Pcs in ASR 1990–2021	Counts (2021)	ASRs per 100,000 (2021)	Pcs in ASR 1990–2021
Global	158,661,976 (148,355,126 to 169,578,900)	1872.8 (1750.2 to 2001)	− 39 (− 40 to − 38)	53,089,008 (48,574,838 to 57,918,266)	664.5 (608.6 to 724.8)	− 37 (− 39 to − 35)	1,274,143 (1,192,624 to 1,360,993)	15.5 (14.5 to 16.6)	− 33 (− 38 to − 29)	69,629,520 (64,851,122 to 74,668,367)	864.6 (804.3 to 925.6)	− 38 (− 42 to − 34)
North Africa and Middle East	16,143,342 (14,957,774 to 17,447,566)	2804.3 (2616.9 to 3017.7)	− 39 (− 41 to − 38)	7,180,905 (6,764,002 to 7,611,518)	1136 (1071.9 to 1201.1)	− 38 (− 40 to − 36)	121,337 (108,067 to 135,131)	20.8 (18.5 to 23)	− 45 (− 50 to − 40)	7,082,601 (6,359,369 to 7,851,629)	1136.7 (1024.1 to 1257.1)	− 50 (− 54 to − 45)
Iran	3,083,158 (2,847,395 to 3,340,682)	3419.9 (3172.3 to 3687.6)	− 52 (− 54 to − 50)	1,146,739 (1,014,219 to 1,286,546)	1341.9 (1193.7 to 1495.1)	− 52 (− 55 to − 50)	19,473 (18,326 to 20,869)	22.6 (21.3 to 24.3)	− 62 (− 65 to − 58)	1,123,673 (1,043,213 to 1,202,228)	1283.4 (1193.7 to 1371.3)	− 64 (− 67 to − 61)
Alborz	102,374 (94,480 to 111,340)	3151.8 (2933.2 to 3406.7)	− 51 (− 53 to − 49)	36,480 (31,943 to 40,947)	1222.7 (1091.4 to 1356.4)	− 51 (− 54 to − 48)	448 (369 to 541)	15.1 (12.6 to 18.3)	− 58 (− 67 to − 45)	26,758 (22,731 to 31,184)	860.8 (733.9 to 1005.8)	− 62 (− 68 to − 53)
Ardebil	41,844 (38,945 to 45,262)	3008.3 (2814 to 3238.7)	− 59 (− 60 to − 57)	15,602 (13,741 to 17,519)	1180.5 (1046.9 to 1323.1)	− 58 (− 61 to − 55)	260 (220 to 304)	19.4 (16.6 to 22.6)	− 64 (− 71 to − 56)	14,596 (12,481 to 16,920)	1069.2 (917.3 to 1235.1)	− 71 (− 76 to − 64)
Bushehr	44,468 (41,164 to 47,939)	3737.9 (3486.5 to 4011)	− 52 (− 54 to − 50)	19,022 (16,768 to 21,443)	1486.3 (1330.8 to 1660.8)	− 52 (− 54 to − 49)	306 (265 to 355)	25.9 (22.3 to 29.9)	− 56 (− 65 to − 45)	17,228 (15,026 to 19,747)	1345.13 (1174.4 to 1534)	− 61 (− 67 to − 53)
Chahar Mahaal and Bakhtiari	37,657 (34,912 to 40,819)	3653 (3405.5 to 3935)	− 53 (− 55 to − 51)	15,041 (13,249 to 16,967)	1454.3 (1297.7 to 1625.4)	− 53 (− 56 to − 50)	224 (191 to 266)	22.1 (18.8 to 26.1)	− 66 (− 73 to − 57)	12,468 (10,821 to 14,375)	1188.7 (1034.2 to 1367)	− 69 (− 74 to − 63)
East Azarbayejan	169,607 (155,390 to 185,015)	3743.4 (3440.7 to 4066.6)	− 52 (− 54 to − 50)	60,464 (53,162 to 68,072)	1464 (1297.6 to 1643.3)	− 52 (− 55 to − 48)	1106 (947 to 1289)	26.2 (22.6 to 30.5)	− 58 (− 67 to − 49)	62,309 (54,078 to 71,250)	1458.6 (1268.9 to 1668)	− 63 (− 69 to − 55)
Fars	269,254 (247,178 to 292,906)	4843.9 (4473.6 to 5237.2)	− 44 (− 45 to − 42)	98,375 (86,689 to 110,796)	1907.7 (1694.6 to 2136.9)	− 44 (− 48 to − 40)	1997 (1667 to 2349)	38 (32.1 to 44.6)	− 53 (− 64 to − 41)	112,660 (96,910 to 129,715)	2115.9 (1826 to 2420.6)	− 54 (− 63 to − 45)
Gilan	123,325 (114,010 to 134,232)	3839.3 (3552.3 to 4162.3)	− 48 (− 50 to − 46)	39,836 (35,038 to 45,126)	1515.1 (1329 to 1705.8)	− 50 (− 54 to − 46)	674 (572 to 777)	23.6 (20.1 to 27.1)	− 60 (− 68 to − 50)	36,532 (31,768 to 41,628)	1317.1 (1157.6 to 1490.9)	− 60 (− 67 to − 52)
Golestan	74,562 (68,814 to 80,821)	3775 (3498.6 to 4072.7)	− 50 (− 52 to − 48)	28,956 (25,701 to 32,382)	1479.9 (1311.6 to 1645)	− 49 (− 53 to − 46)	608 (526 to 693)	32.1 (28 to 36.5)	− 54 (− 62 to − 43)	34,900 (30,568 to 39,689)	1788 (1567.6 to 2029.8)	− 58 (− 65 to − 50)
Hamadan	80,928 (74,686 to 88,008)	4141.4 (3839.8 to 4484.4)	− 51 (− 52 to − 48)	28,214 (24,826 to 31,790)	1614.6 (1426.8 to 1801.1)	− 51 (− 54 to − 47)	558 (481 to 640)	30.3 (26.2 to 34.5)	− 60 (− 68 to − 51)	31,233 (27,377 to 35,339)	1730 (1517.7 to 1944.4)	− 64 (− 70 to − 56)
Hormozgan	68,695 (62,910 to 74,624)	3846.9 (3559.7 to 4154.4)	− 50 (− 52 to − 48)	30,137 (26,293 to 33,923)	1499.6 (1324.3 to 1668.2)	− 49 (− 53 to − 46)	617 (521 to 719)	33.3 (28 to 38.7)	− 58 (− 67 to − 47)	36,954 (31,538 to 42,365)	1861.5 (1586.4 to 2135.2)	− 59 (− 66 to − 51)
Ilam	24,439 (22,568 to 26,540)	3813.8 (3542.6 to 4111.9)	− 49 (− 51 to − 47)	9,510 (8,404 to 10,732)	1514.9 (1349.6 to 1697)	− 48 (− 52 to − 44)	163 (139 to 190)	26.4 (22.6 to 31)	− 57 (− 65 to − 46)	9,249 (7,950 to 10,668)	1439.3 (1241.4 to 1661.9)	
Isfahan	225,206 (208,120 to 244,636)	3725.3 (3458.3 to 4034.3)	− 50 (− 51 to − 48)	77,480 (67,892 to 87,397)	1454 (1281.5 to 1641.7)	− 51 (− 53 to − 48)	1158 (978 to 1388)	20.7 (17.5 to 24.8)	− 60 (− 68 to − 49)	67,426 (58,345 to 78,971)	1207.7 (1048.3 to 1420.5)	− 62 (− 68 to − 54)
Kerman	141,175 (130,040 to 153,160)	4215.7 (3901.2 to 4557.2)	− 50 (− 52 to − 49)	56,041 (49,555 to 62,717)	1646.6 (1456.6 to 1827.3)	− 51 (− 53 to − 48)	1087 (927 to 1262)	33.5 (28.7 to 38.8)	− 62 (− 70 to − 53)	63,615 (55,327 to 72,681)	1860.6 (1619 to 2124.7)	− 63 (− 69 to − 55)
Kermanshah	86,956 (80,286 to 95,104)	3899.2 (3611.4 to 4240.4)	− 51 (− 53 to − 49)	31,123 (27,333 to 35,222)	1522 (1346.1 to 1718)	− 51 (− 54 to − 47)	617 (519 to 723)	29.1 (24.6 to 34)	− 62 (− 70 to − 53)	34,506 (29,386 to 39,644)	1624.7 (1390.4 to 1861.5)	− 63 (− 70 to − 56)
Khorasan-e-Razavi	246,127 (227,397 to 266,061)	3612.9 (3363.8 to 3892.8)	− 57 (− 59 to − 56)	96,040 (84,745 to 108,155)	1402.5 (1243.7 to 1570.9)	− 58 (− 60 to − 55)	1946 (1662 to 2266)	29.8 (25.5 to 34.7)	− 68 (− 74 to − 60)	106,365 (92,021 to 121,619)	1542.5 (1334.2 to 1766.8)	− 70 (− 75 to − 65)
Khuzestan	175,189 (160,997 to 190,136)	3,612.5 (3335 to 3904.7)	− 45 (− 47 to − 43)	70,088 (61,980 to 78,805)	1398.7 (1239.4 to 1568.1)	− 45 (− 49 to − 42)	1129 (980 to 1314)	23.5 (20.2 to 27.3)	− 51 (− 60 to − 39)	68,632 (60,377 to 77,538)	1371.7 (1203.2 to 1547.5)	− 53 (− 60 to − 44)
Kohgiluyeh and Boyer– Ahmad	33,426 (30,433 to 36,756)	4394.8 (4028.3 to 4806.9)	− 46 (− 48 to − 43)	13,850 (11,985 to 15,756)	1719.6 (1510.7 to 1945.1)	− 46 (− 49 to − 42)	229 (197 to 265)	29.1 (25 to 33.8)	− 56 (− 64 to − 46)	14,271 (12,456 to 16,348)	1757.9 (1535.9 to 2005.4)	− 59 (− 66 to − 52)
Kurdistan	69,211 (63,613 to 75,492)	3786.8 (3504.7 to 4105.9)	− 57 (− 58 to − 55)	26,264 (23,179 to 29,681)	1481.4 (1309.5 to 1665.6)	− 57 (− 60 to − 53)	518 (447 to 592)	28.9 (25 to 32.9)	− 68 (− 75 to − 60)	29,260 (25,763 to 33,273)	1608.5 (1414.7 to 1822.5)	− 71 (− 76 to − 66)
Lorestan	62,620 (58,063 to 67,946)	3398.6 (3172.4 to 3668.9)	− 56 (− 58 to − 54)	24,901 (21,889 to 27,907)	1351.1 (1207.5 to 1516.4)	− 55 (− 58 to − 52)	410 (345 to 481)	22.6 (19.2 to 26.2)	− 65 (− 72 to − 57)	22,444 (19,507 to 25,889)	1195.3 (1042.6 to 1372.4)	− 69 (− 75 to − 63)
Continued												

	Prevalence (95% UI)			Incidence (95% UI)			Death (95% UI)			DALYs (95% UI)		
	Counts (2021)	ASRs per 100,000 (2021)	Pcs in ASR 1990–2021	Counts (2021)	ASRs per 100,000 (2021)	Pcs in ASR 1990–2021	Counts (2021)	ASRs per 100,000 (2021)	Pcs in ASR 1990–2021	Counts (2021)	ASRs per 100,000 (2021)	Pcs in ASR 1990–2021
Markazi	64,568 (59,506 to 70,173)	3901.7 (3603.6 to 4217.3)	− 54 (− 56 to − 53)	22,261 (19,589 to 25,189)	1519.7 (1341.9 to 1706)	− 55 (− 58 to − 52)	399 (338 to 467)	25.6 (21.9 to 29.9)	− 68 (− 75 to − 61)	22,605 (19,372 to 25,900)	1477.7 (1273.3 to 1688.4)	− 69 (− 74 to − 63)
Mazandaran	177,010 (163,310 to 193,296)	4278.1 (3956.4 to 4642.9)	− 43 (− 45 to − 41)	59,692 (52,420 to 67,810)	1693.4 (1494.7 to 1903.6)	− 43 (− 46 to − 39)	945 (797 to 1099)	25.2 (21.4 to 29.2)	− 49 (− 60 to − 35)	52,800 (45,290 to 60,197)	1424.8 (1229.5 to 1616.7)	− 52 (− 60 to − 42)
North Khorasan	31,324 (29,042 to 33,736)	3610.6 (3364.4 to 3874.5)	− 54 (− 56 to − 52)	12,185 (10,750 to 13,679)	1396.4 (1235.4 to 1572.3)	− 54 (− 57 to − 51)	259 (224 to 295)	30.2 (26.2 to 34.4)	− 66 (− 72 to − 57)	14,715 (12,938 to 16,584)	1668.9 (1474.7 to 1879.3)	− 69 (− 74 to − 63)
Qazvin	49,792 (46,191 to 53,949)	3481.9 (3238.9 to 3748.8)	− 57 (− 58 to − 55)	18,922 (16,692 to 21,341)	1369.2 (1214.7 to 1534.4)	− 56 (− 59 to − 54)	346 (290 to 403)	25.1 (21.2 to 29.2)	− 66 (− 73 to − 58)	18,486 (15,721 to 21,365)	1297.4 (1106.4 to 1500.3)	− 71 (− 76 to − 64)
Qom	33,716 (31,178 to 36,481)	2379.2 (2214.7 to 2553)	− 64 (− 65 to − 63)	12,979 (11,507 to 14,652)	905.6 (807.8 to 1019.6)	− 64 (− 66 to − 62)	169 (140 to 214)	12.4 (10.4 to 15.6)	− 71 (− 77 to − 62)	10,066 (8,522 to 12,499)	691.4 (585.9 to 853)	− 73 (− 78 to − 66)
Semnan	29,151 (27,082 to 31,617)	3528.9 (3290.9 to 3810.6)	− 55 (− 56 to − 53)	11,098 (9,699 to 12,536)	1385.1 (1226.7 to 1548.9)	− 55 (− 58 to − 52)	177 (148 to 211)	22.2 (18.7 to 26.3)	− 66 (− 73 to − 57)	9,818 (8,377 to 11,588)	1194.7 (1021.7 to 1412)	− 69 (− 74 to − 61)
Sistan and Baluchistan	92,721 (85,081 to 100,917)	3952.6 (3648.5 to 4290)	− 43 (− 46 to − 40)	47,655 (41,696 to 53,709)	1502 (1324.4 to 1684.2)	− 43 (− 47 to − 39)	1041 (891 to 1214)	38.2 (32.7 to 45)	− 54 (− 64 to − 40)	65,149 (56,941 to 74,253)	2155.3 (1866.2 to 2478.3)	− 57 (− 65 to − 46)
South Khorasan	31,062 (28,702 to 33,424)	3597.5 (3335.3 to 3867.7)	− 53 (− 55 to − 51)	12,527 (11,063 to 13,944)	1408.6 (1250.4 to 1565.94)	− 53 (− 56 to − 49)	223 (194 to 255)	25.7 (22.3 to 29.3)	− 65 (− 71 to − 56)	12,677 (11,295 to 14,169)	1419.7 (1266.4 to 1587.2)	− 70 (− 75 to − 63)
Tehran	290,506 (270,764 to 313,282)	1774.8 (1660.8 to 1907.3)	− 55 (− 56 to − 53)	92,118 (81,709 to 103,731)	663.8 (592.9 to 746.5)	− 55 (− 58 to − 52)	456 (366 to 677)	3.1 (2.5 to 4.6)	− 57 (− 67 to − 43)	35,632 (29,164 to 45,891)	233.2 (191.3 to 304)	− 61 (− 67 to − 53)
West Azarbayejan	123,979 (114,158 to 135,385)	3519.7 (3255.5 to 3817.6)	− 53 (− 54 to − 50)	48,286 (42,619 to 54,474)	1373.4 (1219.7 to 1536.9)	− 52 (− 55 to − 49)	877 (751 to 1022)	25.8 (22.2 to 30)	− 59 (− 67 to − 49)	51,097 (44,905 to 58,645)	1433.7 (1255.6 to 1638.1)	− 64 (− 69 to − 56)
Yazd	42,874 (39,616 to 46,379)	3618.4 (3358.8 to 3894.6)	− 51 (− 52 to − 49)	16,901 (14,873 to 19,016)	1417.1 (1266.8 to 1586.2)	− 51 (− 54 to − 48)	248 (201 to 297)	21.6 (17.7 to 25.9)	− 65 (− 72 to − 55)	14,440 (12,098 to 16,923)	1202.7 (1008.5 to 1407.2)	− 65 (− 72 to − 58)
Zanjan	39,391 (36,513 to 42,539)	3383.9 (3152.3 to 3633.3)	− 59 (− 61 to − 57)	14,693 (12,945 to 16,581)	1333.7 (1191.5 to 1496.7)	− 61 (− 63 to − 58)	277 (239 to 319)	24.6 (21.2 to 28.2)	− 67 (− 73 to − 59)	14,781 (12,936 to 16,875)	1292.9 (1132.6 to 1471.2)	− 72 (− 77 to − 65)

Prevalence, incident cases, deaths, and DALYs of transport injuries for both sexes in 2021, and the percentage change in age-standardized rates (per 100,000 population) from 1990 to 2021 based on the GBD database. *DALY* Disability-adjusted life-years, *UI* uncertainty interva, *ASR* age-standardized rate, *Pcs* percentage changes, *GBD* global burden of disease.

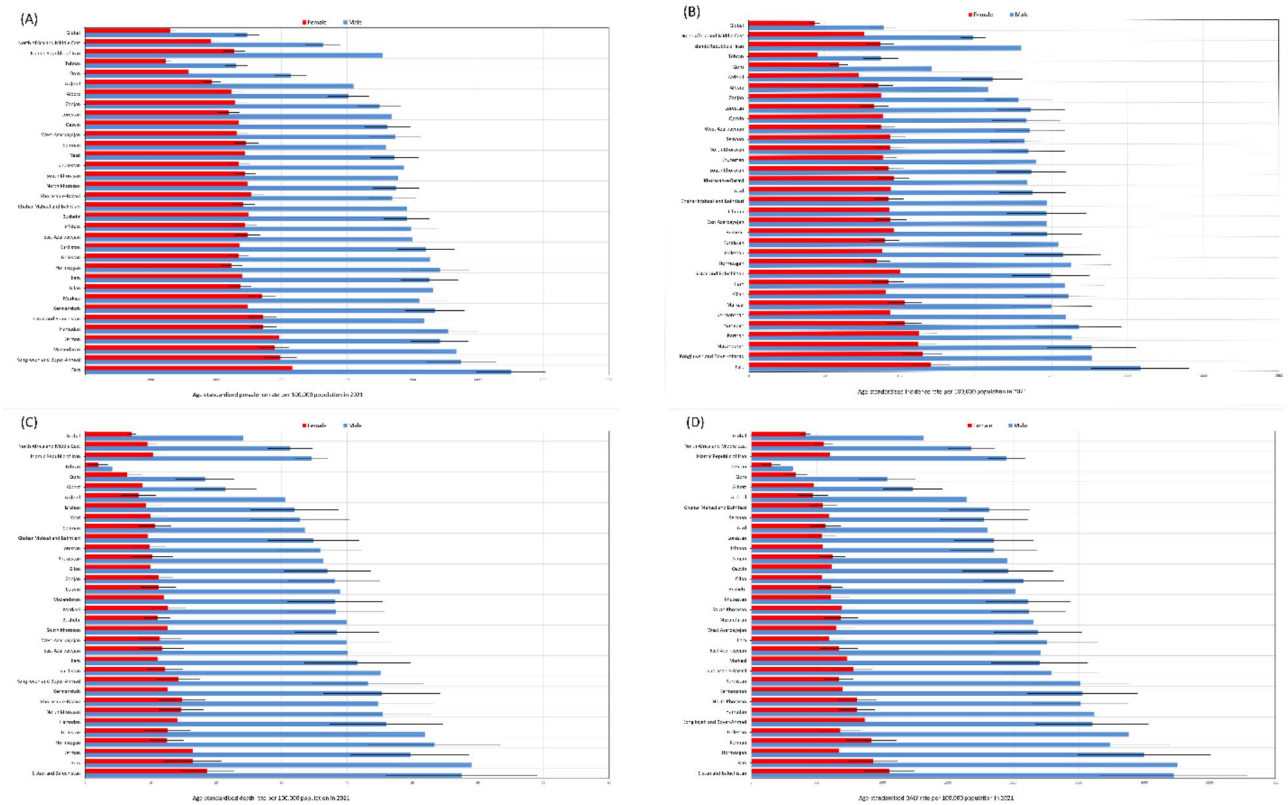

Fig. 1. Age-standardized point prevalence (**A**), incidence (**B**), death (**C**), and DALYs (**D**) rate for transport injuries (per 100,000 population) globally, in the MENA region, in Iran, and in Iran's provinces in 2021 by region and sex. *DALY* disability-adjusted life-years, *MENA* Middle East and North Africa.

100,000 by 2021. However, Mazandaran (– 52%; 95% UI: – 60 to – 42%), Khuzestan (– 53%; 95% UI: – 60 to – 44%), and Fars (– 54%; 95% UI: – 63 to – 45%) had the smallest reduction in DALY rates (Fig. 2D; Table 1).

Age and sex patterns

For both sexes, the overall prevalence of TI peaked in 2021 in the 35–39 age group and then declined with age. Moreover, the prevalence rate reached its highest point in the 90–94 age group for both sexes (Fig. 3A).

Incident cases of TI reached a high point in ages 20–39 for males and in age groups of 0–4 and 30–34 for females. Furthermore, for males, the incidence rate of TI cases peaked in the 20–24 age group and then declined as age increased. However, this pattern was not evident in females (Fig. 3B).

The death rate of TI cases reached a high point in the 20–24 age group for males, followed by a decline, after which it resumed an upward trend as age advanced. In females, the death rate steadily increased with age. Furthermore, the number of TI deaths was highest in the 30–34 and 35–39 age groups for both sexes (Fig. 3C).

The DALY number of TI cases was highest in the 30–34 and 35–35 age groups for both sexes. In addition, the DALY rate peaked at the 20–24 age group in males. But, in females, the DALY rate maintained an upward trend as their age increased (Fig. 3D).

Burden by injury category

Motor vehicle road injuries had the highest age-standardized rates of prevalence (1441.9; 95% UI: 1259.5 to 1666.9), incidence (670; 95% UI: 585.3 to 772.8), death (11.83; 95% UI: 9.88 to 15.25), and DALY (661.8; 95% UI: 572.4 to 823.2) in Iran in 2021, followed by pedestrian and motorcyclist road injuries with DALY rates of 338.4 (95% UI: 218.1 to 452.8) and 193.5 (95% UI: 153.2 to 235.9), respectively. Cyclist road injuries had higher prevalence and incidence rates compared to other road and transport injuries; however, their death and DALY rates did not show this pattern (Fig. 4A–D and Supplementary Table 5).

Burden by socio-demographic index (SDI)

In 2021, the age-standardized DALY rate decreased as the SDI increased, indicating a negative relationship between the SDI and age-standardized DALY rate for TIs. Fars, Kerman, Markazi, and Hamadan had higher than anticipated age-standardized DALYs. In contrast, age-standardized DALYs in Ardebil, Tehran, and Qom were lower than anticipated (Fig. 5).

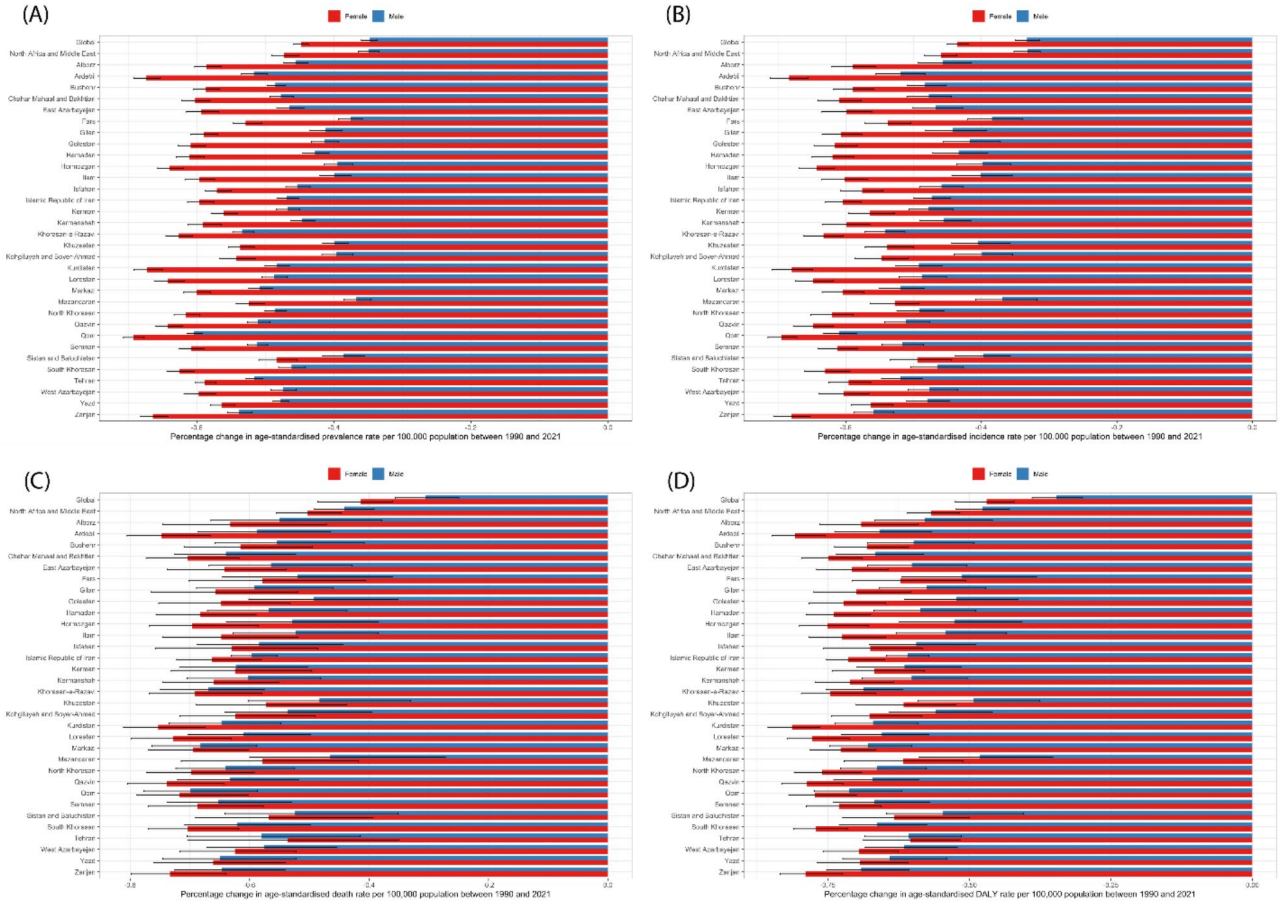

Fig. 2. Percentage change in the prevalence rate (**A**), incident rate (**B**), death rate (**C**), and DALY rate (**D**) for transport injuries (per 100,000 population) globally, in the MENA region, in Iran, and in Iran's provinces from 1990 to 2021, by region and sex. *DALY* disability-adjusted life-years, *MENA* Middle East and North Africa.

Discussion

The current study used the GBD 2021 data to determine the burden of TIs in Iran from 1990 to 2021. In 2021, there were 3.083 million prevalent cases, 1.147 million incident cases, and 19.472 thousand deaths in Iran. Iran had higher prevalence, incidence, DALY, and Death rates compared the global and MENA regions, however it showed a more noticeable reduction in these rates over the study period. The burdon of TIs varied across provinces and among different age and sex groups. Among the provinces, highest DALY rates were reported for Fars and Sistan-Baluchistan, with neither having much improvement since 1990. Males, particularly those aged 20–24, had the highest incidence and DALY rates, while older adults (70 + years) had the highest prevalence and death rates. A negative association was observed between the Socio-demographic Index (SDI) and DALYs, highlighting the influence of socioeconomic factors on injury burden.

The burden of TIs is assessed using prevalence, incidence, mortality, and DALYs. While the prevalence of TIs indicates the number of individuals living with injury-related disabilities, the incidence rate highlights the ongoing occurrence of new injury cases, emphasizing the persistent risk of transport injuries despite existing preventive measures. The mortality rate shows the burden of TIs resulting in death, whereas DALYs, which combine both YLLs due to premature death and YLDs, reflect the impact of TIs in terms of both fatal and non-fatal outcomes[10]. Consequently, factors such as road safety laws, vehicle safety standards, transportation infrastructure, injury severity, and post-injury healthcare influence both the occurrence and outcomes of TIs and their overall burden[15].

Compared with the global and MENA regions, Iran had higher prevalence, incidence, and DALY rates of TIs in both 1990 and 2021. This finding is consistent with a previous study that reported higher rates in Iran using GBD 2019 data[2]. Iran has experienced 2.5 times population growth along with rapid urbanization in recent decades[16,17]. Rapid urbanization and an inadequate transport system increase the risk of transport injuries. For instance, overcrowded and poorly maintained roads contribute to a higher risk of traffic accidents[18]. In addition, weak enforcement of traffic laws, such as speed limits, seatbelt usage, and driving under the influence, can lead to increased traffic accidents. Lower safety standards for cars, lack of proper public awareness, and common reckless behavior among drivers may also increase the risk of TIs[19,20]. A systematic review of 20 studies in Iran reported roadway defects and improper road surfaces as mortality risk factors for traffic injuries[19]. Despite having higher rates of TIs, Iran experienced a more noticeable reduction in these rates between 1990 and 2021.

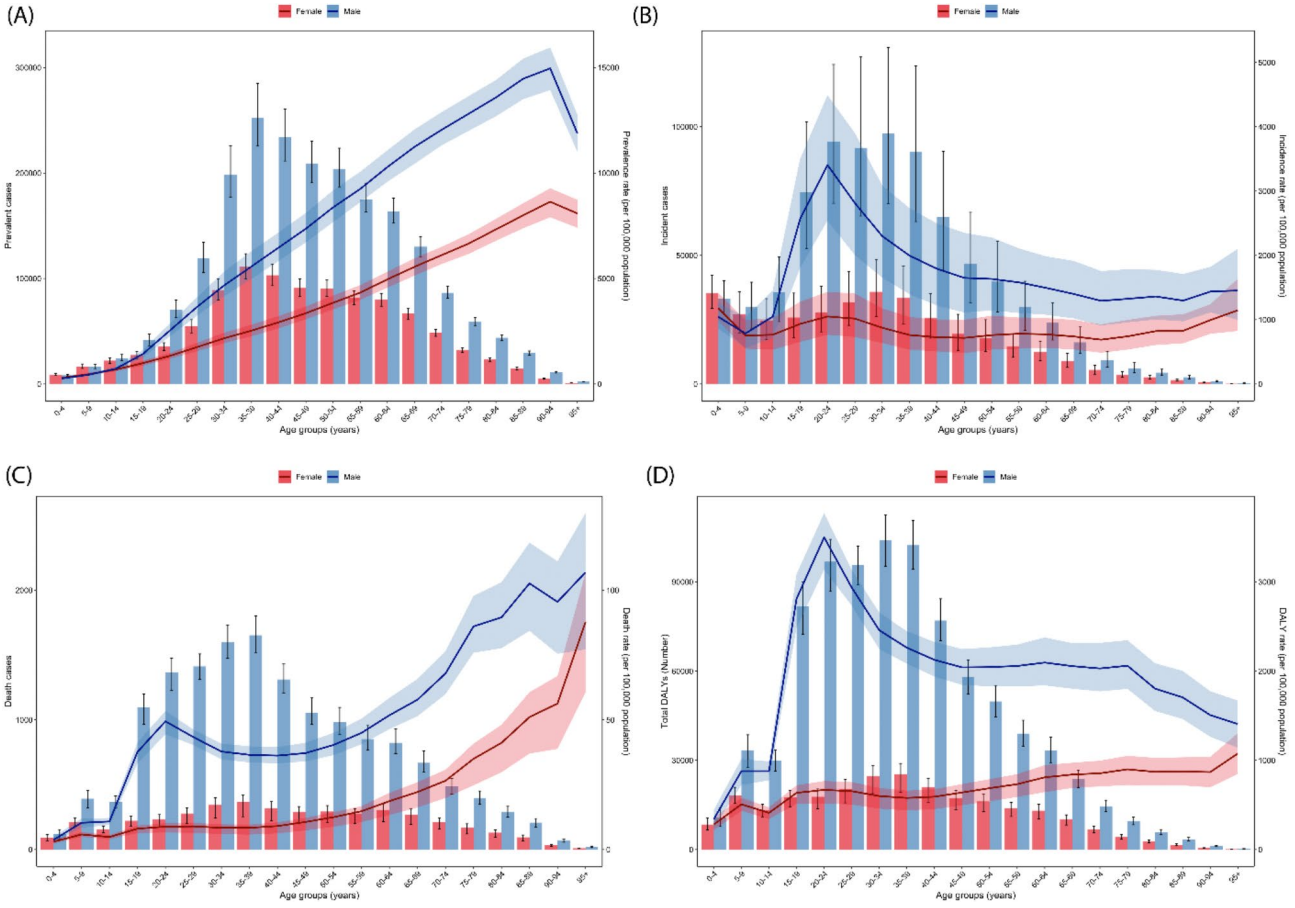

Fig. 3. Prevalent cases count and prevalence (**A**), Incident cases count and incidence rate (**B**), Death cases count and death rate (**C**), and the number of DALYs and DALY rate (**D**) for transport injuries (per 100,000 population) in Iran, by age and sex in 2021; shading indicates upper and lower uncertainty intervals of 95%, respectively. *DALY* disability-adjusted life-years, *MENA* Middle East and North Africa.

This could be due to the availability of safer transportation options, such as switching to automobiles with higher safety standards and using public transportation[21,22]. The recent increase in public awareness and official efforts in Iran may have contributed to these results. A study reported a 3.3% decrease in deaths due to road traffic injuries after enforcement of mandatory use of seatbelts[23,24].

As reported in this study, there was a negative association between the SDI and DALYs of TIs. In most regions, a higher SDI indicates greater access to vehicles with higher safety standards. Furthermore, regions and provinces with a higher SDI tend to have properly developed transport infrastructure, better road maintenance, and better road services[15,25]. However, various social and economic factors may play a role in the SDI and TI. For instance, in some low-income countries, living in urban regions with a higher SDI would mean more access to motor vehicles and more TIs compared with rural areas, where access to motor vehicles is limited[26]. By contrast, in higher-income countries, residents of higher SDI regions may prefer to travel with air and rail transport vehicles, with a lower likelihood of injury[15]. This emphasizes the importance of considering the local context when interpreting data on the relationship between the SDI and TIs.

Among the different types of transport injuries, road traffic injuries compose a substantial proportion of it in Iran. As reported, motor vehicle, pedestrian, and motorcyclist road injuries are the three leading causes of the burden of TIs in Iran. Considering the high rate of traffic injuries among pedestrians and motorcycle riders it would be helpful to put on initiatives such as encouraging the use of helmets and installing safety measures like speed bumps and necessary road signs. In the cyclist road injuries subcategory, we observed lower death and DALY rates; however, the prevalence and incidence rates were not as low. This could be explained by the fact that cyclists typically travel at lower speeds and avoid highways and roads designed for higher-speed vehicles, which may reduce the severity of injuries in this subcategory. As a subcategory of TIs, other transport injuries, such as air and rail travel, contribute to a lesser extent to Iran's overall burden of TIs. Air and rail travel are known for their lower injury risk, yet in the event of an incident, they can result in severe injuries and multiple casualties, which should not be overlooked in programs aimed at reducing burden of TIs[15].

According to the present study, the burden of TIs did not have a consistent pattern across the provinces in Iran. Among the provinces, Tehran, Fars, and Khorasan-e-Razavi had the highest prevalence of TIs. However, the highest incidence rates were reported for Fars, Kohgiluyeh and Boyer-Ahmad, and Mazandaran. Despite

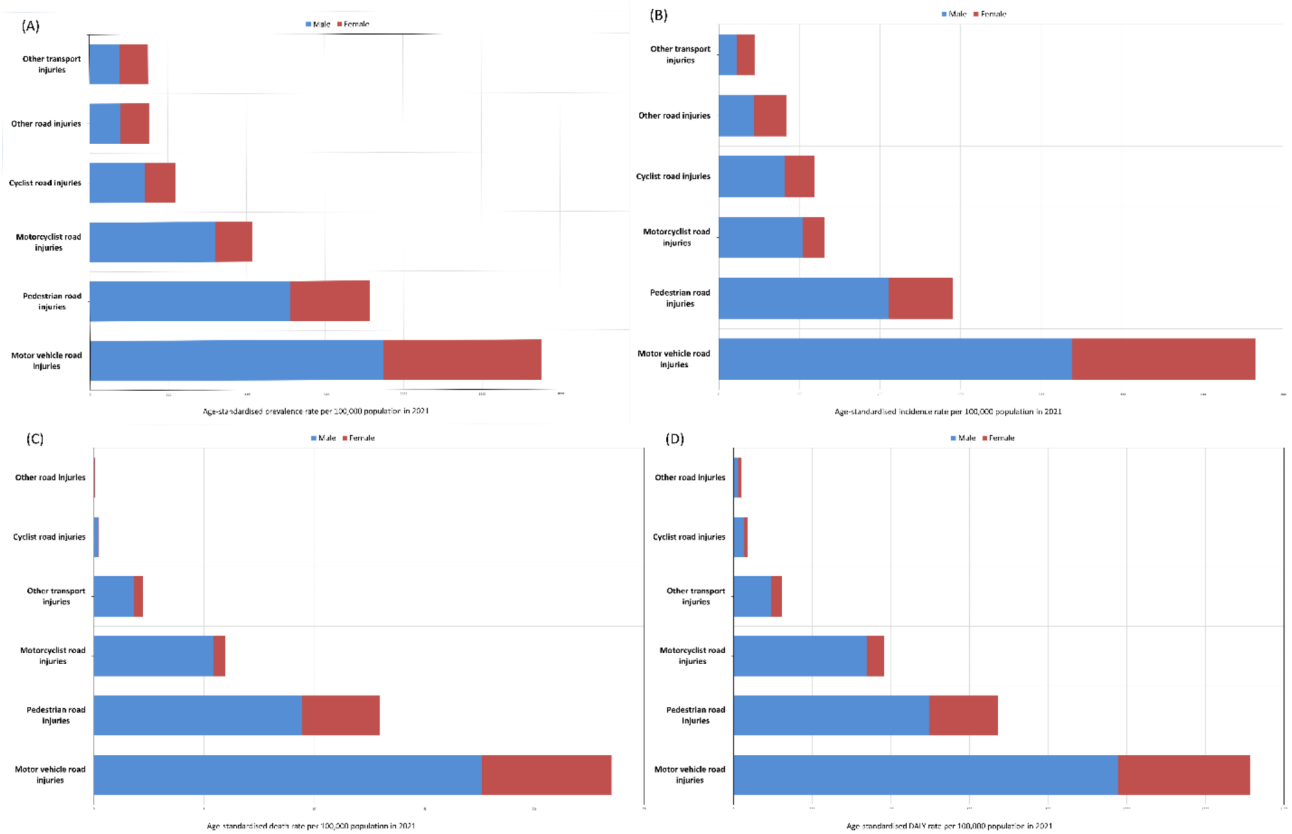

Fig. 4. Age-standardized point prevalence (**A**), incidence (**B**), death (**C**), and DALYs (**D**) rate for transport injuries (per 100,000 population) in Iran, in 2021 by injury category. *DALY* disability-adjusted life-years.

its dense transportation landscape, Tehran, as Iran's capital, had the lowest overall burden of TIs, likely because of better infrastructure and stricter enforcement of traffic laws. In contrast, Sistan-Baluchistan and Fars had the highest mortality and DALY rates, indicating a significant fatal and nonfatal impact of TIs in these regions. Furthermore, these provinces were among those with the least improvement in DALY rates and burden of TIs over time. This highlights how the issue of TIs has remained persistent, underlining the need to address factors such as road safety, traffic law enforcement, proper healthcare, and post-injury care access in those areas.

A previous study also reported a significant disparity in the burden of TIs across the provinces in Iran. The Tehran and Sistan-Baluchistan provinces were reported to have the lowest and highest burdens of road traffic injuries in 2019, respectively[2]. Other studies reported similar heterogeneity across provinces. Shavaleh et al. reported a higher incident rate of road traffic crashes in the central and eastern provinces of Iran[27]. However, in contrast to our findings, Najimi-Varzaneh et al. reported the lowest pooled road traffic accident rate for Fars province in their systematic review, which included studies published between 1995 and 2018. This may be explained by the different methods applied compared with GBD studies, which use a consistent, global analytical approach, likely integrating recent hospital and official records[8,28].

Mentioned heterogeneity also exists in other countries[29]. A previous study that analyzed the provincial distribution of traffic accidents in Turkey reported a higher death rate for roads connecting major cities (Erdogan)[30]. Variations in transportation infrastructure, road conditions, compliance with traffic laws, social behaviors, and healthcare access could contribute to the reported disparities[31]. These differences highlight the importance of considering province-specific factors during the policymaking process.

According to our findings, the burden of TIs was not the same for the different age groups in Iran, with distinct trends of rate and number in prevalence, incidence, mortality, and DALYs. Males in the 20–24 age group had the highest incidence and DALY rates, along with a peak in the death rate. Other studies have reported similar findings in this age group. Chen et al. reported the highest incidence rates of transport injuries for men in the 20–24 age group globally[32]. The high incidence rate in this age group can partly be due to behavioral factors; for instance, young adults tend to manifest risk-taking behaviors more frequently[4]. Additionally, the high DALY and mortality rates in early adulthood indicate the severity and long-term consequences of their injuries. However, this pattern was less prominent among females in the same age group in Iran, underlining a distinction in contributing factors according to sex.

For the 30–39 age range, both males and females had higher prevalence, incidence, mortality, and DALYs. The 30–39 age range tends to have a higher exposure to road traffic because of their workforce participation, daily mobility, or involvement in responsibilities such as commuting and transporting family members. Despite the similarities, the disparity across age groups for number of prevalence, incidence, mortality, and DALYs

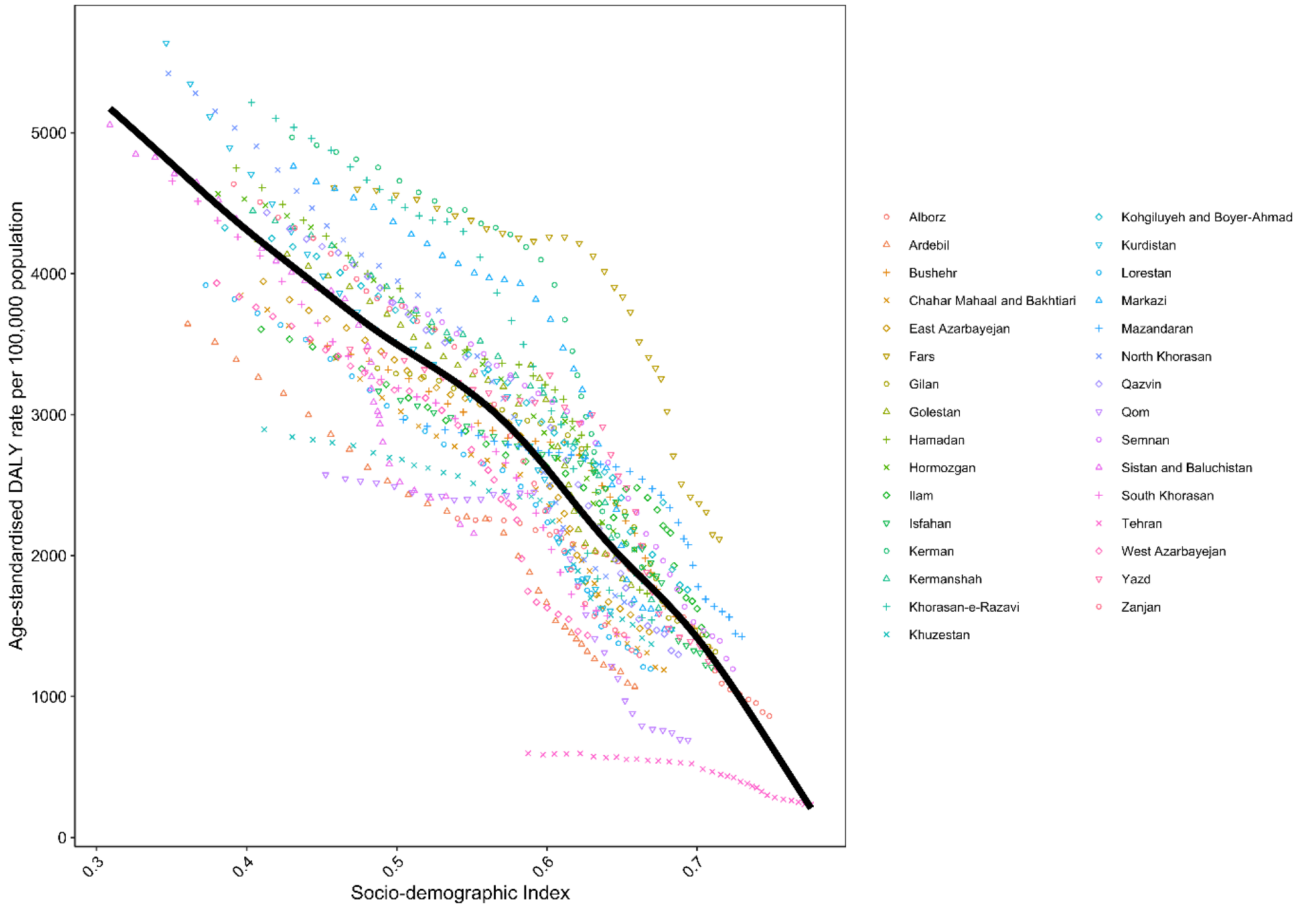

Fig. 5. Age-standardized DALY rates of transport injuries for 31 provinces of Iran in 2021 by SDI; expected values based on the sociodemographic index and injury rates across all provinces are marked by the black line. The observed age-standardized DALY rates are shown as 32 plotted points for each province from 1990 to 2021. Provinces with a higher-than-expected DALY rate are above the black line, and provinces with a lower-than-expected DALY rate are below. DALY: disability-adjusted life-years; SDI: socio-demographic index.

was more noticeable for males. This can be explained by men being more likely to work in jobs that involve frequent transportation, particularly those that require intercity travel, which has a high risk of resulting in severe injuries[33,34].

Individuals aged 70 and older had the highest prevalence and death rates in our study. Due to their limited recovery capability and the likelihood of underlying conditions, such as low bone density, they may experience a cumulative effect of persisting prior injury-related disabilities, leading to a higher prevalence and death rate from TIs. However, in males, older individuals had a lower DALY rate compared to young adults. This can be explained by the contribution of YLDs and YLLs in calculating DALYs. Therefore, in cases of disability or premature death due to TIs, older individuals lose fewer potential years of life based on their expected lifespan compared to younger ones, which results in smaller DALYs for the older population[15,35].

Limitations

This study had some limitations. First, the present study applied GBD data for analysis, which relies on modeling methods rather than primary data, to provide estimates in case of a lack and/or dispersion of data. Second, considering the social and economic factors unique to every region, it may be challenging to interpret data, especially according to the SDI and gender groups. Third, although the COVID-19 pandemic has been reported to affect TIs both in terms of incidence and medical service provision, it was not evaluated in this study[36].

Conclusion

The burden of TIs in Iran has decreased significantly since 1990; however, it remains higher than that in the Global and MENA regions. TIs show an uneven distribution across provinces as well as age and gender groups in Iran. Provinces of Fars and Sistan-Baluchistan had a high burden of TIs persistently, however, Tehran had the lowest rates of burden despite its population. Young adults (20–24 years) had the highest incidence rate of TIs, while older adults (70 + years) had the highest prevalence and mortality rates.

Given these findings, applying targeted interventions would mitigate the impact of TIs. While older people would most benefit from better post-injury care and road safety measures, driver education programs like GDL

could help young adults avoid TIs. Therefore, more research is required to examine demographic and regional risk factors as well as to assess the efficacy of these interventions.

Data availability

"Data sets generated during the current study are available from the corresponding author on reasonable request (Hassan Soleimanpour) upon reasonable request."

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Author contributions
"AA, MP, MB, SA, MS, SEJG and HS performed the data collection, literature review, and drafting of the manuscript. HS, AA and MB undertook the major parts of the study design and performed the statistical analysis. All authors reviewed the manuscript."

Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
This study was registered with registration number: 75348. All methods were implemented in accordance with the relevant guidelines and regulations. Furthermore, all procedures in the study involving human participants were performed in accordance with the ethics standards of the institutional/national research committee and with the Helsinki Declaration and its later amendments or comparable ethics standards. The ethics committee of Tabriz University of Medical Sciences approved the study (IR.TBZMED.REC.1403.956).

Consent for publication
The data presented in the manuscript and its supplemental files included no details on the patients and, thus, no consent was required for publication.

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