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# Trends in Cardiovascular Risk-Assessment Coverage and Risk-Category Distribution in an EHR-Integrated Primary Care Program in Southern Iran, 2019–2025

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## Abstract

### Background

Cardiovascular disease remains the leading cause of premature death in Iran and across low- and middle-income countries. Iran's IraPEN program embeds WHO-based cardiovascular risk scoring into the national electronic health record (EHR) system, yet how risk-category distributions and screening coverage have shifted over time remains poorly understood.

### Methods

This repeated cross-sectional study was conducted using 167,250 cardiovascular risk assessments among adults aged 40–80 years in Jahrom County, southern Iran, between 2019 and 2025. Ten-year CVD risk was estimated using the WHO Eastern Mediterranean risk prediction model. Age-standardized proportions (ASPs) per 1,000 screened individuals were calculated using the WHO standard population, and temporal trends were assessed by log-linear regression, reported as annual percent change (APC) with 95% confidence intervals.

### Results

Women accounted for 54.7% of assessments. The majority of participants fell into the ≤10% risk category (86.8%), with 3.5% classified as moderate risk (10–20%). ASPs rose significantly in both the ≤10% (APC=15.1%; p=0.009) and 10–20% (APC=14%; p=0.02) categories. Higher-risk categories trended upward but without statistical significance. Among women, the >30% risk category showed a statistically significant increase. Screening coverage expanded substantially, most notably among adults aged ≥60 years.

### Conclusion

Growth in EHR-integrated cardiovascular screening coincided with greater detection of individuals across all risk strata. These trends most likely reflect a combination of expanded coverage, improved case ascertainment, and changing cardiometabolic profiles within the screened population.

### Keywords

Cardiovascular risk; Electronic health records; WHO risk prediction model; Obesity; Hypertension; Iran

## Introduction

Cardiovascular disease (CVD) remains the leading cause of death worldwide and represents a major public health burden in Iran and other low- and middle-income countries (LMICs) (1, 2). Although age-standardized CVD mortality has declined in many high-income countries, the overall burden of CVD continues to increase in LMICs, partly reflecting population ageing and the persistent or increasing prevalence of modifiable risk factors such as hypertension, diabetes, obesity, and tobacco use (1-3). Strengthening primary prevention therefore requires approaches that can identify individuals at elevated cardiovascular risk and support appropriate risk-based preventive care at the primary healthcare level.

Absolute cardiovascular risk assessment is an important component of contemporary primary prevention strategies. The 2021 European Society of Cardiology and 2019 American College of Cardiology/American Heart Association guidelines support risk-based approaches to cardiovascular prevention, whereby estimated absolute cardiovascular risk can inform the intensity of preventive interventions (3) . Integrating systematic risk assessment into routine primary healthcare can therefore facilitate the identification of individuals across different risk categories and provide an opportunity to monitor the reach of risk-assessment services and the distribution of predicted risk within healthcare systems.

Iran adapted the World Health Organization (WHO) Package of Essential Noncommunicable Disease (PEN) interventions into the IraPEN program, which was piloted between 2016 and 2018 and subsequently expanded within the national health system (4, 5) . The program incorporated standardized cardiovascular risk assessment into primary healthcare services for adults aged 40 years and older. The pilot evaluation reported changes in estimated cardiovascular risk and several cardiovascular risk factors following program implementation (4) . Integration of IraPEN activities into Iran's electronic health record (EHR) infrastructure has further enabled routine cardiovascular risk assessments to be documented within the primary healthcare system, creating an opportunity to examine changes in assessment coverage and risk-category distributions over time.

Despite the implementation of IraPEN and the availability of EHR-based cardiovascular risk assessments, temporal changes in assessment coverage and the distribution of predicted cardiovascular risk categories among assessed adults remain insufficiently characterized at the subnational level in Iran. Previous national studies have largely relied on periodic population-based cross-sectional surveys, which provide important information on cardiovascular risk factors but are less suited to describing year-to-year changes in routine risk-assessment activity within primary healthcare services (6, 7) . Moreover, how cardiovascular risk-assessment coverage and risk-category distributions changed during the COVID-19 period, and whether these patterns varied by sex and area of residence, remains insufficiently documented in subnational EHR data (8) .

Importantly, temporal changes in EHR-based risk-category distributions may reflect multiple processes, including changes in the characteristics of the assessed population, expansion of assessment coverage, healthcare access, case ascertainment, data completeness, and changes in underlying cardiometabolic risk. Therefore, changes in the observed distribution of risk categories should not necessarily be interpreted as changes in population-level cardiovascular risk. Nevertheless, monitoring these patterns within routine EHR data can provide useful information on programme reach and changes in the populations reached by cardiovascular risk assessment.

This study described temporal trends in cardiovascular risk-assessment coverage and risk-category distribution among adults aged 40–80 years assessed through the primary healthcare network of Jahrom County, southern Iran, from 2019 to 2025. Specifically, we described cardiovascular risk-factor profiles, examined temporal changes in annual assessment coverage, assessed age-standardized distributions of predicted CVD risk categories, and explored variation in these patterns by sex and area of residence. By characterizing routine EHR-based cardiovascular risk assessment over time, this study aimed to provide evidence relevant to

monitoring and planning primary cardiovascular prevention services in Iran and comparable LMIC settings.

## Methods

### Study design and setting

This repeated cross-sectional study used electronic health record (EHR) data from the integrated primary healthcare system of Jahrom County, southern Iran, covering January 1, 2019, to December 31, 2025. The study was conducted within the IraPEN programme, the Iranian adaptation of the World Health Organization (WHO) Package of Essential Noncommunicable Disease Interventions (PEN), which integrates cardiovascular disease (CVD) risk assessment into primary healthcare services. The programme applies the WHO Eastern Mediterranean Region cardiovascular risk prediction model to estimate an individual's predicted risk of a cardiovascular event.

The study examined temporal changes in documented cardiovascular risk assessment and the distribution of predicted CVD risk categories among adults aged 40–80 years registered in the primary healthcare system.

### Study population and EHR data

The study population comprised adults aged 40–80 years who were registered and eligible for cardiovascular risk assessment in the EHR system during each calendar year from 2019 through 2025. Annual EHR extracts provided aggregate counts of registered eligible individuals and those with a valid cardiovascular risk assessment.

The EHR system automatically deduplicates records within each calendar year. When an individual undergoes multiple cardiovascular risk assessments during the same year, only the most recent valid assessment is retained in the annual dataset. Thus, each individual contributes a maximum of one observation per calendar year to the annual assessment and risk-category estimates.

Persistent person-level identifiers were not available in the aggregate data; therefore, records could not be linked across calendar years. Consequently, an individual may have contributed an observation in multiple years, but the extent of such cross-year recurrence could not be determined. The sum of annual observations across 2019–2025 therefore does not represent the number of unique individuals in the overall study period.

### Cardiovascular risk assessment and risk categories

Cardiovascular risk was assessed using the algorithm implemented in the IraPEN EHR system and based on the WHO Eastern Mediterranean cardiovascular risk prediction model. The analysis was based on predicted risk categories generated by the programme rather than on observed cardiovascular events.

Five mutually exclusive categories were used:

1. No documented cardiovascular risk factor;
2. ≤10% predicted risk;
3. 10% to ≤20% predicted risk;
4. 20% to ≤30% predicted risk; and
5. 30% predicted risk.

The category "no documented cardiovascular risk factor" was treated as a distinct category and was not included within the ≤10% risk category. The five categories were mutually exclusive and collectively represented the distribution of individuals with a valid annual risk assessment.

The cardiovascular risk factors documented in the EHR included body mass index (BMI), waist circumference, hypertension, diabetes, prediabetes, uncontrolled diabetes, hypercholesterolemia, and tobacco use. These variables were used to characterize the documented cardiovascular risk profile within the IraPEN programme.

The aggregate EHR output did not separately identify individuals with incomplete or insufficient information for risk calculation; therefore, the number or proportion of incomplete assessments could not be quantified. No imputation was performed.

**Definitions of cardiovascular risk factors**

BMI was calculated as weight in kilograms divided by height in meters squared (kg/m²). Overweight was defined as a BMI of 25.0–29.9 kg/m² and obesity as a BMI ≥30.0 kg/m². Abdominal obesity was defined as a waist circumference ≥90 cm.

Hypertension was defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg or documented use of antihypertensive medication. Prehypertension was defined as systolic blood pressure of 120–139 mmHg and/or diastolic blood pressure of 80–89 mmHg.

Diabetes mellitus was defined by a physician diagnosis, use of antidiabetic medication, or fasting plasma glucose ≥126 mg/dL on two repeated measurements. Prediabetes was defined as fasting plasma glucose of 100–125 mg/dL, and uncontrolled diabetes as HbA1c >10%.

Hypercholesterolemia was defined as total cholesterol >200 mg/dL. Current tobacco use was defined as self-reported active smoking documented during healthcare visits.

**Cardiovascular risk-assessment coverage**

Annual documented cardiovascular risk-assessment coverage was calculated as the proportion of registered eligible adults who had a valid cardiovascular risk assessment documented during the corresponding calendar year. The numerator was the number of individuals with a valid annual assessment after within-year deduplication, and the denominator was the total number of registered eligible adults aged 40–80 years in that year.

$$\text{Coverage}_t\ (\%) = (N_{\text{assessed},t} / N_{\text{eligible},t}) \times 100$$

where $N_{assessed,t}$ denotes the number of individuals with a valid cardiovascular risk assessment in year $t$, and $N_{eligible,t}$ denotes the number of registered eligible adults in that year.

This indicator represents **year-specific documented assessment coverage**. It does not represent the proportion of unique individuals assessed at least once during the entire 2019–2025 period because cross-year individual linkage was not possible.

**Age-standardized distribution of cardiovascular risk categories**

For each calendar year, the distribution of the five risk categories was calculated among individuals with a valid annual cardiovascular risk assessment. Direct age standardization was used to account for differences in the age structure of the assessed population across calendar years.

The assessed population was categorized into four age groups: 40–50, 51–60, 61–70, and 71–80 years. Age-specific proportions for each risk category were weighted according to the corresponding age distribution of the WHO World Standard Population(11). Age-standardized proportions (ASPs) were reported per 1,000 assessed individuals.

The denominator for these standardized proportions was the total number of individuals with a valid cardiovascular risk assessment in the corresponding year, rather than the total registered eligible population. Thus, ASPs describe the **age-standardized distribution of predicted CVD risk categories among assessed individuals** and are distinct from annual assessment coverage.

**Statistical analysis**

Annual numbers and proportions of individuals with documented cardiovascular risk assessment and the distribution of cardiovascular risk categories were summarized descriptively. Annual assessment coverage and age-standardized proportions for each risk category were calculated for 2019–2025.

Temporal trends were evaluated using log-linear regression models, with calendar year as the independent variable. The annual percentage change (APC) and corresponding 95% confidence interval (CI) were estimated from the regression coefficient as:

$$\ln(Y_t) = \alpha + \beta t$$
$$APC\ (\%) = [\exp(\beta) - 1] \times 100$$

where $Y_t$ represents the annual value of the indicator and $\beta$ is the estimated regression coefficient for calendar year. Two-sided tests were used, with statistical significance defined as $p<0.05$.

Given the availability of only seven annual observations, trend estimates were interpreted cautiously. Joinpoint regression was not performed because the limited number of time points would not support reliable estimation of multiple temporal changes.

A sensitivity analysis excluding 2022 was conducted to examine the potential influence of the COVID-19 pandemic and associated disruption of routine healthcare services on the estimated trends. Stratified analyses by sex and place of residence were considered exploratory because of the limited number of annual observations and the potential instability of estimates for smaller subgroups or risk categories.

Because persistent person-level identifiers were unavailable, potential within-person correlation resulting from individuals contributing observations in multiple calendar years could not be identified or modeled. Accordingly, longitudinal methods such as generalized estimating equations or mixed-effects models were not applicable to the available aggregate data. The analyses were therefore performed at the annual aggregate level and interpreted as a **repeated cross-sectional EHR surveillance analysis**, rather than as an assessment of individual-level longitudinal changes in cardiovascular risk.

All statistical analyses were performed using [statistical software, version].

### Ethical considerations

The study was approved by the Ethics Committee of Jahrom University of Medical Sciences (IR.JUMS.REC.1402.112). The analysis was based on de-identified aggregate EHR data without directly identifiable personal information. The requirement for individual informed consent was waived by the institutional ethics committee.

## Results

### Study Population

Between 2019 and 2025, a total of 167,250 CVD risk assessments were performed among adults aged 40–80 years in Jahrom County. Individuals with a history of myocardial infarction or stroke were excluded from risk estimation analyses.

The largest proportion of participants belonged to the 40–50-year age group (32.9%, 95% CI: 32.6–33.1), and age distribution differed significantly by sex ($p<0.001$), with men more commonly represented in younger age categories. Baseline characteristics and cardiovascular risk factors are summarized in Table 1.

**Table 1. Baseline Characteristics and Cardiovascular Risk Factors by Sex (2019–2025)**

| Variable | | Total (n=167,250) n (%) [95% CI] | Male (n=75,820) n (%) [95% CI] | Female (n=91,441) n (%) [95% CI] | p-value |
|---|---|---|---|---|---|
| Age | 40–50 | 55,354 (33.5%) [32.6–34.1] | 26,916 (35.5%) [35.2–35.9] | 28,438 (31.1%) [30.8–31.4] | <0.001 |
| | 51–60 | 40,001 (24.2%) [23.8–25.2] | 18,879 (24.9%) [24.6–25.2] | 21,122 (23.1%) [22.8–23.4] | <0.001 |

| | | | | | |
|---|---|---|---|---|---|
| | **61–70** | 48,337 (29.3%) [28.7–29.5] | 21,911 (28.9%) [28.6–29.2] | 26,426 (28.9%) [28.6–29.2] | 0.89 |
| | **71–80** | 21,514 (13.02%) [13.0–13.3] | 10,084 (13.3%) [13.1–13.5] | 11,430 (12.5%) [12.3–12.7] | <0.001 |
| **BMI** | **25-30** | 55,520 (33.2%) [33.0–33.5] | 23,166 (30.6%) [30.3–31.0] | 32,354 (35.4%) [35.1–35.7] | <0.001 |
| | **>30** | 25,995 (15.5%) [15.3–15.7] | 6,965 (9.2%) [9.0–9.4] | 19,030 (20.8%) [20.5–21.1] | <0.001 |
| **Abdominal obesity** | | 44,076 (26.4%) [26.2–26.6] | 17,977 (23.7%) [23.4–24.0] | 26,099 (28.5%) [28.2–28.8] | <0.001 |
| **Hypertension** | **(SBP≥140 or DBP≥90mmHg)** | 31,185 (18.6%) [18.4–18.8] | 10,322 (13.6%) [13.4–13.9] | 20,863 (22.8%) [22.5–23.1] | <0.001 |
| | **Prehypertension (120–140)** | 44,332 (26.5%) [26.3–26.7] | 22,244 (29.3%) [29.0–29.6] | 22,088 (24.2%) [23.9–24.5] | <0.001 |
| | **Uncontrolled hypertension** | 2,236 (1.3%) [1.25–1.36] | 877 (1.2%) [1.09–1.26] | 1,359 (1.5%) [1.38–1.54] | <0.001 |
| **Diabetes** | **Diabetes** | 17,648 (10.5%) [10.4–10.7] | 11,439 (15.1%) [14.9–15.4] | 6,209 (6.8%) [6.6–7.0] | <0.001 |
| | **Pre diabetes** | 12,223 (7.3%) [7.2–7.4] | 7,118 (9.4%) [9.2–9.6] | 5,105 (5.6%) [5.4–5.8] | <0.001 |
| | **Uncontrolled diabetes** | 7,950 (4.8%) [4.7–4.9] | 5,127 (6.8%) [6.6–7.0] | 2,823 (3.1%) [3.0–3.3] | <0.001 |
| **Tobacco use** | | 3,458 (2.1%) [2.0–2.1] | 3,126 (4.1%) [4.0–4.3] | 332 (0.36%) [0.32–0.40] | <0.001 |
| **High cholesterol** | **(>200 mg/dL)** | 14,106 (8.4%) [8.3–8.6] | 4,944 (6.5%) [6.4–6.7] | 9,162 (10.0%) [9.8–10.2] | <0.001 |
| **History of stroke** | | 1,131 (0.67%) [0.63–0.71] | 557 (0.7%) [0.64–0.76] | 565 (0.6%) [0.56–0.65] | 0.18 |
| **History of MI** | | 1,491 (0.9%) [0.85–0.94] | 852 (1.1%) [1.02–1.16] | 639 (0.7%) [0.65–0.75] | <0.001 |
| **No risk factor** | | 15,365 (9.2%) [9.1–9.3] | 7,828 (10.3%) [10.1–10.6] | 7,537 (8.2%) [8.0–8.4] | <0.001 |
| **≤10% risk** | | 145,276 (86.8%) [86.6–87.0] | 65,188 (85.9%) [85.6–86.2] | 80,088 (87.6%) [87.4–87.8] | <0.001 |
| **10–20% risk** | | 5,856 (3.5%) [3.4–3.6] | 2,519 (3.3%) [3.2–3.5] | 3,337 (3.6%) [3.5–3.8] | 0.002 |
| **20–30% risk** | | 577 (0.3%) [0.28–0.33] | 213 (0.28%) [0.24–0.32] | 364 (0.40%) [0.36–0.44] | 0.001 |
| **>30% risk** | | 176 (0.1%) [0.08–0.12] | 69 (0.09%) [0.07–0.11] | 107 (0.12%) [0.10–0.15] | 0.04 |

- Data are presented as number (percentage) with 95% confidence intervals.
- P-values were calculated using the chi-square test for sex comparisons.
- A two-sided p-value <0.05 was considered statistically significant

## Prevalence of Cardiovascular Risk Factors

Obesity (BMI ≥30 kg/m²) was present in 15.5% of participants (95% CI: 15.3–15.7), while abdominal obesity was found in 26.4% (95% CI: 26.2–26.6). Women had higher rates of both general and abdominal obesity compared with men ($p<0.001$).

Hypertension was identified in 18.6% of participants (95% CI: 18.4–18.8), while 26.5% met criteria for prehypertension; hypertension was more prevalent among women, whereas prehypertension was more common in men ($p<0.001$).

Diabetes was present in 10.5% (95% CI: 10.4–10.7), with higher rates among men than women (15.1% vs. 6.8%, $p<0.001$); prediabetes and uncontrolled diabetes followed the same pattern.

High total cholesterol (>200 mg/dL) was identified in 8.4% and was more prevalent among women. Tobacco use was uncommon overall (2.1%) but substantially higher among men (4.1% vs. 0.36%, $p<0.001$).

## Ten-Year Cardiovascular Risk Distribution

The large majority of participants fell into the ≤10% predicted 10-year CVD risk category (86.8%, 95% CI: 86.6–87.0). Moderate risk (10–20%) was found in 3.5%, while high-risk (20–30%) and very high-risk (>30%) categories together accounted for less than 1% of all assessments.

Women were more frequently classified in the ≤10% group compared with men (87.6% vs. 85.9%, $p<0.001$), though the absolute differences across strata were modest (Table 1).

## Temporal Trends in Cardiovascular Risk-Assessment Coverage

Cardiovascular risk-assessment coverage increased across all age groups between 2019 and 2025 (Figure 1), with the largest absolute increase observed among adults aged ≥60 years. Among those aged 60–70 years, coverage increased from 23.5% in 2019 to 60.7% in 2025, while among those aged 70–80 years, it increased from 24.4% to 51.7%.

A temporary decline in coverage was observed between 2021 and 2022 across all age groups, followed by a marked recovery from 2022 onward. Throughout the study period, coverage remained consistently lower among younger adults than among older age groups (Figure 1).

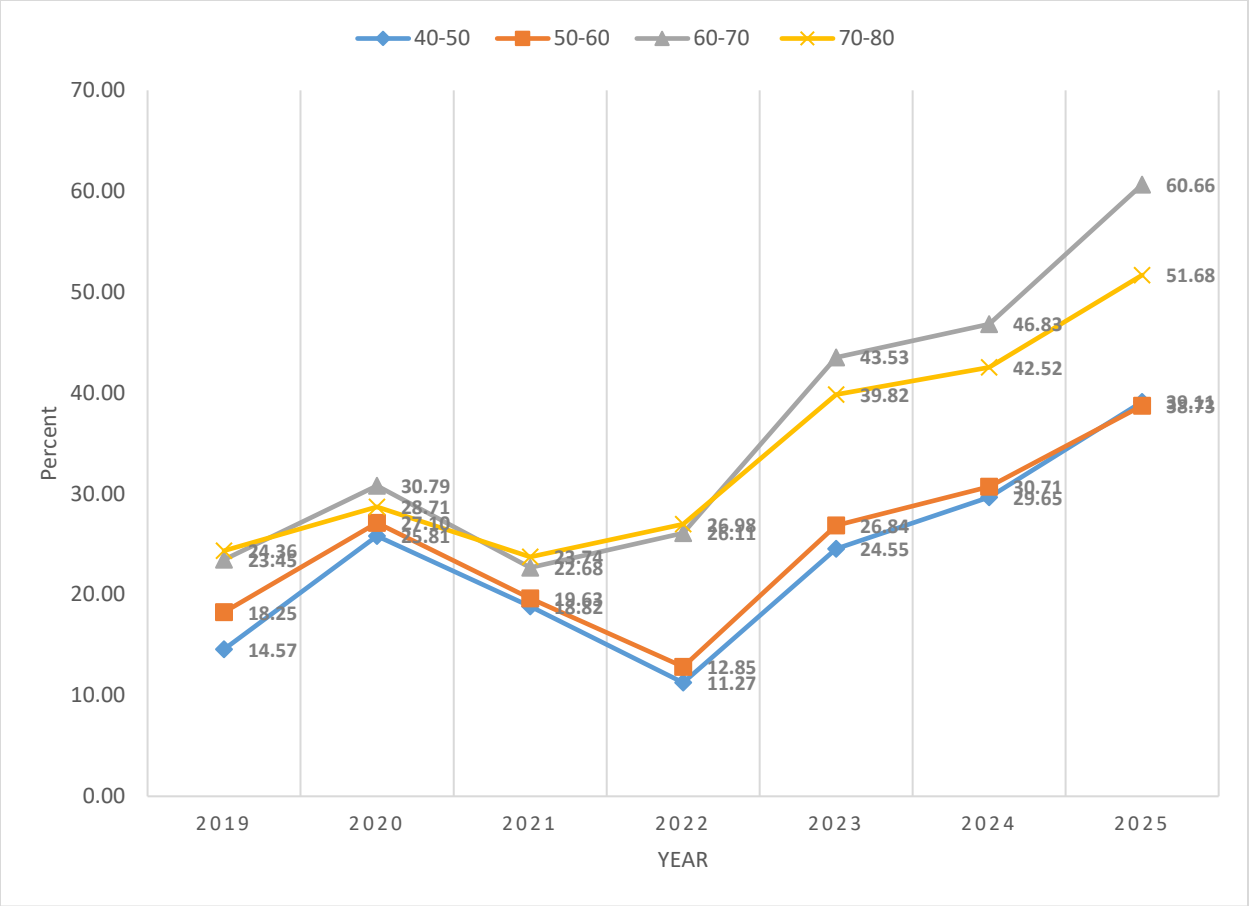



**Figure 1: Temporal trends in cardiovascular risk-assessment coverage across age groups, 2019–2025**

**Temporal Trends in Predicted Cardiovascular Risk Categories**

Log-linear regression analyses showed statistically significant increases in ASPs of low- and moderate-risk cardiovascular categories between 2019 and 2025. The ≤10% risk category rose from 298.4 to 759.9 per 1,000 population (APC=15.1%, 95% CI: 7.7–22.9; p=0.009), while the 10–20% category increased from 73.1 to 155.8 (APC=14.0%, 95% CI: 5.4–23.4; p=0.022). Higher-risk categories (>20%) also trended upward, but these changes did not reach statistical significance. Sensitivity analyses excluding 2022 produced comparable APC estimates, supporting the robustness of the primary findings (Table 2).

**Table 2. Temporal Trends of Age-standardized Distribution 10-Year Cardiovascular Risk Categories Sex**

| Risk Level | ASPs 2019 | ASPs 2025 | APC % (95% CI) | P Value | *Sensitivity APC % (95% CI) | Sensitivity P value | **P value |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| <10 | 298.44 | 759.88 | 15.06 (7.71 to 22.92) | 0.009 | 15.06 (9.44 to 20.97) | 0.005 | 1.000 |
| 10–20 | 73.05 | 155.80 | 14.03 (5.37 to 23.40) | 0.022 | 14.03 (6.51 to 22.08) | 0.020 | 1.000 |
| 20–30 | 8.94 | 14.75 | 10.61 (−1.58 to 24.31) | 0.151 | 10.61 (−2.69 to 25.73) | 0.198 | 1.000 |
| >30 | 1.61 | 2.20 | 9.72 (−5.12 to 26.88) | 0.266 | 9.72 (−5.29 to 27.10) | 0.284 | 1.000 |
| No risk factor | 48.79 | 36.88 | −2.63 (−18.92 to 16.94) | 0.787 | −2.63 (−13.33 to 9.41) | 0.678 | 1.000 |

**Abbreviations:** APC, annual percent change; CI, confidence interval; ASPs, age-standardized proportion per 1,000 population.
APC estimated using join point log-linear regression.
*Sensitivity analysis performed after exclusion of year 2022
** p value for difference between primary APC estimates and sensitivity APC estimates

### Sex-Stratified Temporal Trends in Predicted Cardiovascular Risk Categories

Sex-stratified analyses showed broadly similar temporal patterns in men and women (Table 3), with the largest increases in the ≤10% and 10–20% risk categories in both groups.

Among men, the ≤10% category rose from 122.6 in 2019 to 360.9 in 2025 (APC=16.5%, p=0.010); among women, from 175.8 to 399.0 (APC=13.9%, p=0.010).

Statistically significant increases in selected higher-risk categories were identified among women, though absolute rates remained low throughout. Sensitivity analyses excluding 2022 did not materially alter APC estimates.

**Table 3. Temporal Trends of Age-standardized Distribution 10-Year Cardiovascular Risk Categories by Sex**

| Sex | Risk Category | ASPs 2019 | ASPs 2025 | APC % (95% CI) | P Value | *Sensitivity APC % (95% CI) | Sensitivity P value | **P value |
|---|---|---|---|---|---|---|---|---|
| Male | <10% | 122.62 | 360.91 | 16.53 (8.15 to 25.55) | 0.0101 | 16.53 (9.36 to 24.17) | 0.0092 | 1.0 |
| | 10–20% | 28.46 | 69.37 | 17.54 (7.22 to 28.85) | 0.0183 | 17.54 (8.88 to 26.88) | 0.0144 | 1.0 |
| | 20–30% | 3.22 | 5.85 | 13.59 (-1.28 to 30.71) | 0.1352 | 13.59 (-2.89 to 32.87) | 0.1863 | 1.0 |
| | >30% | 0.90 | 0.85 | 4.73 (-40.59 to 84.64) | 0.8793 | 4.73 (-19.28 to 35.89) | 0.7454 | 1.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No risk factor | 22.87 | 16.96 | -3.97 (-20.01 to 15.29) | 0.6819 | -3.97 (-12.67 to 5.59) | 0.4495 | 1.0 |
| **Female** | <10% | 175.82 | 398.97 | 13.94 (7.16 to 21.15) | 0.0088 | 13.94 (9.25 to 18.83) | 0.0037 | 1.0 |
| | 10–20% | 44.60 | 86.43 | 11.57 (3.95 to 19.75) | 0.029 | 11.57 (4.70 to 18.89) | 0.0279 | 1.0 |
| | 20–30% | 5.72 | 8.90 | 8.92 (-2.41 to 21.56) | 0.1879 | 8.92 (-2.83 to 22.08) | 0.2162 | 1.0 |
| | >30% | 0.71 | 1.35 | 14.57 (5.11 to 24.87) | 0.027 | 14.57 (4.21 to 25.95) | 0.0482 | 1.0 |
| | No risk factor | 25.92 | 19.92 | -1.21 (-18.07 to 19.12) | 0.9034 | -1.21 (-14.07 to 13.57) | 0.8723 | 1.0 |

**Abbreviations:** APC, annual percent change; CI, confidence interval; ASPs, age-standardized proportion per 1,000 population.
APC estimated using join point log-linear regression.
*Sensitivity analysis performed after exclusion of year 2022
** p value for difference between primary APC estimates and sensitivity APC estimates

**Residence-Stratified Temporal Trends in Predicted Cardiovascular Risk Categories**

Residence-stratified analyses showed increasing temporal trends across both urban and rural populations (Table 4).

Among rural residents, a notable increase was observed in the 20–30% risk category; the >30% category and the no-risk-factor category trended downward, though these changes were not statistically significant.

Among urban residents, the most pronounced increase occurred in the 10–20% risk category, which rose from 25.2 in 2019 to 76.5 in 2025 (APC=20.7%, 95% CI: 6.8–36.5; p=0.011). The ≤10% category also showed an upward trend, though the p-value was borderline (APC=18.8%, 95% CI: −0.8 to 42.1; p=0.057). Higher-risk categories showed variable but generally upward patterns without reaching statistical significance. Sensitivity analyses excluding 2022 yielded consistent direction and magnitude of APC estimates across most categories.

**Table 4. Temporal Trends of Age-standardized Distribution 10-Year Cardiovascular Risk Categories by Place of Residence**

| Residence | Risk Category | ASPs 2019 | ASPs 2025 | APC % (95% CI) | P Value | *Sensitivity APC % (95% CI) | P value | ** P value |
|---|---|---|---|---|---|---|---|---|
| **Rural** | <10% | 320.51 | 438.52 | 7.97 (1.79 to 14.53) | 0.0512 | 7.97 (1.82 to 14.49) | 0.0625 | 1.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10–20% | 73.95 | 82.41 | 0.39 (-10.96 to 13.20) | 0.9513 | 0.39 (-11.92 to 14.43) | 0.9559 | 1.0 |
| | 20–30% | 2.15 | 9.55 | 18.18 (5.50 to 32.39) | 0.0344 | 18.18 (4.10 to 34.17) | 0.0613 | 1.0 |
| | >30% | 1.36 | 0.4 | -17.46 (-29.19 to -3.80) | 0.0576 | -17.46 (-30.39 to -2.14) | 0.0917 | 1.0 |
| | No risk factor | 70.8 | 25.2 | -8.43 (-25.20 to 12.10) | 0.4326 | -8.43 (-21.67 to 7.06) | 0.3315 | 1.0 |
| **Urban** | <10% | 153.44 | 355.29 | 18.77 (3.58 to 36.19) | 0.057 | 18.77 (6.95 to 31.90) | 0.0324 | 1.0 |
| | 10–20% | 25.2 | 76.51 | 20.73 (9.93 to 32.60) | 0.011 | 20.73 (10.31 to 32.14) | 0.015 | 1.0 |
| | 20–30% | 4.92 | 6.63 | 10.86 (-8.40 to 34.17) | 0.3381 | 10.86 (-10.28 to 36.98) | 0.3936 | 1.0 |
| | >30% | 0.61 | 1.39 | 24.66 (-5.71 to 64.82) | 0.1825 | 24.66 (-7.74 to 68.44) | 0.2245 | 1.0 |
| | No risk factor | 58.53 | 15.93 | -4.34 (-36.68 to 44.51) | 0.8414 | -4.34 (-33.97 to 38.60) | 0.8261 | 1.0 |

**Abbreviations:** APC, annual percent change; CI, confidence interval; ASPs, age-standardized proportion per 1,000 population.
APC estimated using join point log-linear regression
*Sensitivity analysis performed after exclusion of year 2022
** p value for difference between primary APC estimates and sensitivity APC estimates

## Discussion

In this population-based repeated cross-sectional study using routine EHR data from southern Iran, we found substantial temporal increases in WHO-defined cardiovascular risk-category distributions alongside marked expansion of screening coverage between 2019 and 2025. The sharpest increases occurred in the ≤10% and 10–20% risk categories, while higher-risk categories showed smaller and less statistically precise upward trends. Coverage expanded across all age groups, particularly among older adults, interrupted by a temporary dip during the COVID-19 period.

A central interpretive consideration is that rising ASPs of cardiovascular risk categories do not straightforwardly indicate worsening population cardiovascular health. These trends most likely reflect the compounding influence of expanding screening coverage, improved healthcare access, maturation of the IraPEN surveillance infrastructure, and better identification of individuals who were previously outside the healthcare system. As a screening program matures, the composition

of the screened population can shift considerably, altering observed risk distributions in ways that are not purely epidemiological.

**Cardiovascular Risk Distribution and Comparison with National and Regional Data**

The predominance of assessments in the ≤10% risk category aligns with previous national Iranian studies using WHO and GloboRisk prediction models. Analyses based on STEPS survey data have similarly found that most Iranian adults fall within lower predicted risk strata, even in the presence of high prevalence of individual cardiometabolic risk factors such as obesity, hypertension, and diabetes. Expansion (6, 7) of screening in the present study may additionally have drawn in lower-risk individuals who were previously underrepresented in routine healthcare contacts.

**Temporal Trends in Cardiovascular Risk-Assessment Coverage and Risk Categories**

The substantial increase in cardiovascular risk-assessment coverage over time particularly among adults aged ≥60 years, is among the most important findings of this study. Older adults carry the highest absolute cardiovascular risk and therefore stand to benefit most from structured preventive intervention. Growing uptake in this age group likely reflects the progressive embedding of IraPEN into chronic disease management and routine primary care activities within the regional system(3, 12).

The transient decline in risk-assessment coverage during 2021–2022 was temporally consistent with the COVID-19 pandemic and probably reflects disruption of routine primary care services. Similar reductions in preventive cardiovascular activities, hypertension monitoring, diabetes care, and noncommunicable disease screening have been widely reported internationally during this period. The recovery observed after 2022 suggests that healthcare delivery systems adapted following the acute pandemic phase(8, 13).

**Sex-Stratified Patterns**

The sex-specific cardiometabolic patterns observed in the present study are broadly consistent with emerging evidence from Middle Eastern and other LMIC populations. Substantially higher prevalence of general and abdominal obesity was documented among women, whereas higher prevalence of diabetes, prediabetes, and uncontrolled diabetes was identified among men. This apparent paradox has been reported elsewhere: higher overall adiposity among women in LMIC settings has been attributed to complex interactions between sociocultural, behavioral, reproductive, and environmental determinants, including lower physical activity, pregnancy-related weight retention, and gender-related constraints on lifestyle modification and access to preventive care. Among men, adverse metabolic consequences have been observed at comparatively lower levels of adiposity, a pattern that has been linked to greater visceral fat accumulation, higher insulin resistance, and earlier ectopic fat deposition. Epidemiological and experimental evidence further suggests that progression to type 2 diabetes tends to occur at younger ages and lower BMI thresholds among men than women. Collectively, these mechanisms may partly explain the coexistence of higher obesity prevalence among women and higher diabetes burden among men observed in the present study, highlighting the importance of sex-sensitive cardiovascular prevention strategies within EHR-integrated primary care systems(14-17).

## Residence-Stratified Patterns

Residence-stratified analyses suggested steeper increases in selected cardiovascular risk categories among rural populations. This may reflect improving access to structured cardiovascular risk assessment in rural settings, where preventive care utilization has historically lagged behind urban areas (18-22). Consequently, Expansion of structured screening programs in rural networks may initially increase detection of high-risk individuals who were previously unidentified. However, given the study design, ascertainment effects cannot be separated from underlying epidemiological change, and rural–urban differences should be interpreted with caution.

## Implications for Public Health Policy

The present study has several important strengths. The analysis was based on a large real-world EHR dataset encompassing more than 167,000 cardiovascular risk assessments over a seven-year period. The study additionally evaluated temporal patterns across the COVID-19 period and incorporated sex-stratified and residence-stratified analyses to explore heterogeneity across population subgroups. Use of routine EHR data also enhances the translational and policy relevance of the findings for implementation-oriented cardiovascular surveillance in low- and middle-income settings.

## Strengths and Limitations

A major strength of this study is the use of a large real-world EHR dataset comprising 167,250 annual person-level observations from an integrated primary healthcare system over seven years. The study provides a programme-level assessment of temporal changes in cardiovascular risk-assessment coverage and risk-category distribution, including the COVID-19 period. The use of standardized WHO cardiovascular risk prediction methods within the IraPEN framework also supports methodological consistency and comparability with other WHO PEN-based programmes.

Several limitations should be considered. First, the repeated cross-sectional design precludes causal inference and assessment of individual-level cardiovascular risk trajectories. Although records were deduplicated within each calendar year, persistent person-level identifiers were unavailable; therefore, observations could not be linked across years, and the extent of repeated contributions by the same individuals could not be determined. Second, expansion of assessment coverage may have changed the composition of the assessed population over time, meaning that observed changes in risk-category distributions may partly reflect broader programme reach and case ascertainment rather than changes in underlying population-level risk. Third, routinely collected EHR data may be subject to incomplete documentation, measurement variability across healthcare centres, and misclassification of self-reported variables such as tobacco use. Fourth, because assessment was based on individuals with valid EHR records rather than random population sampling, the assessed population may not fully represent the broader eligible population. Finally, the absence of linkage with cardiovascular event and mortality registries prevented evaluation of the programme's association with subsequent clinical outcomes.

## Conclusion

Cardiovascular risk-assessment coverage within the EHR-integrated primary healthcare system increased substantially between 2019 and 2025, particularly among older adults, alongside temporal changes in the age-standardized distribution of predicted cardiovascular risk categories. These findings provide real-world evidence on changes in the reach and composition of routine cardiovascular risk assessment in primary care. However, changes in risk-category distributions should be interpreted cautiously, as they may reflect changes in assessment coverage and population composition as well as underlying cardiometabolic risk. The findings therefore describe programme-level temporal patterns rather than individual-level changes in cardiovascular risk.

## Author Contributions

**Consent for publication**: Not applicable.

**Competing interests:** The authors declare that there are no conflicts of interest.

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All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Razieh Zahedi affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as originally planned have been fully explained.

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**Ethical Approval and Consent to Participate:** Ethical Approval and Consent to Participate

This study was approved by the Ethics Committee of Jahrom University of Medical Sciences (IR.JUMS.REC.1402.112). The requirement for informed consent was waived because the study used fully anonymized secondary electronic health record data and no identifiable personal information was available to the investigators.

**Data Availability Statement:** The datasets generated and/or analyzed during the current study are not publicly available because they contain data derived from electronic health records and are subject to institutional and ethical restrictions. De-identified data may be made available from the corresponding author upon reasonable request and with permission from Jahrom University of Medical Sciences.

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