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Research Article

Altitudinal, Temporal and Spatial Distribution of Cardiovascular Disease Incidence in Four Western Provinces (Guizhou, Qinghai, Sichuan and Yunnan) of China, 2023–2024

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How To Cite: Wang, Z.; Ren, Q.; Wang, X.; et al. Altitudinal, Temporal and Spatial Distribution of Cardiovascular Disease Incidence in Four Western Provinces (Guizhou, Qinghai, Sichuan and Yunnan) of China, 2023–2024. *iCirculation* **2026**, *1*(2), 12. https://doi.org/10.53941/icirculation.2026.100012

Received: 30 April 2026
Revised: 7 September 2026
Accepted: 9 September 2026
Published: 23 September 2026

Abstract: Background: Western China, characterized by high altitude, hypoxia, cold climate, and large seasonal temperature variations, exhibits a high level of cardiovascular disease (CVD) incidence, yet the underlying environmental risk factors remain poorly understood. Methods: CVD data were obtained from the national surveillance database managed by the National Center for Cardiovascular Diseases, China. Disease burden was assessed using incidence rate and age-standardized incidence rate (ASIR). Spatial autocorrelation was evaluated using Global Moran's I, and a generalized linear model (GLM) was employed for multivariable analysis. Results: The overall ASIR decreased from 600.21 per 100,000 in 2023 to 531.92 per 100,000 in 2024. Regional variation was evident, with Yunnan showing consistently higher incidence and Qinghai exhibiting the lowest survival. Stroke accounted for the largest proportion of CVD burden. Males and older individuals had higher incidence levels, while seasonal peaks occurred in spring and winter. Descriptive analyses suggested differences in incidence across altitude strata, but multivariable regression revealed no independent association between altitude and CVD incidence. Conclusions: CVD incidence in western China varies by region, season, and population, with stroke predominating. Higher rates occur in males and the elderly, highlighting the need for targeted prevention strategies and strengthened primary healthcare services.

Keywords: cardiovascular diseases; altitude; temporal distribution; spatial epidemiology; western China

1. Introduction

Cardiovascular diseases remain a major global public health problem, and their burden continues to increase, China is no exception [1,2]. In recent years, the absolute number of cardiovascular disease cases has been steadily increasing [3], a study in China reported that in 2023 there were already 330 million individuals with CVD, meaning that one in every four people is affected, highlighting the severe challenges in prevention and control [4,5].

Numerous epidemiological studies have investigated CVD, however, most have focused on individual-level risk factors, such as age, sex, BMI, and unhealthy lifestyle behaviors [6–8]. Few studies have examined environmental factors, such as high altitude, hypoxia, cold climate, and large seasonal temperature variations [9,10], in the Chinese population. The geographic environment of western China is highly distinctive, characterized by high altitude, hypoxia, cold climate, and large seasonal temperature variations [11]. Moreover, studies have shown that CVD incidence in this region ranks highest among the three major regions of China [5]. However, the underlying risk factors remain unclear, highlighting the urgent need for further investigation.

Therefore, this study aimed to comprehensively assess the overall CVD burden in four western provinces, illustrate monthly and seasonal temporal trends, quantify the association between altitude strata and CVD risk, and provide evidence to support precision public health interventions and optimized healthcare resource allocation.

2. Materials and Methods

2.1. Study Design and Population

A retrospective, population-based observational study was conducted to investigate the altitudinal, temporal and spatial distribution of cardiovascular disease (CVD) incidence in four western provinces of China (Guizhou, Qinghai, Sichuan and Yunnan) from 1 January 2023 to 31 December 2024. The study population included permanent residents aged 18 years or older who had lived in the surveillance areas for at least six consecutive months. Individuals under 18 years of age, those with duplicate case reports, and residents whose permanent domicile was outside the surveillance sites were excluded. The denominator for calculating incidence-related indicators was the population aged 18 years and above, derived from the Seventh National Population Census of China [5].

2.2. Data Source

Data were obtained from the national surveillance database maintained by the National Center for Cardiovascular Diseases, China. To ensure data quality and representativeness, the selection of surveillance sites comprehensively considered socioeconomic development, population size, and urbanization level. Principal component analysis was first used to construct composite indicators, followed by K-means clustering to stratify the regions. Subsequently, multistage random sampling method was used to determine the final surveillance areas.

Ethical approval and informed consent were waived due to the retrospective, anonymized and population-based nature of the study.

2.3. Stratification and Grouping

Stratified analyses were performed according to the following variables: province (Guizhou, Qinghai, Sichuan, Yunnan), gender (male, female), season (spring: March–May; summer: June–August; autumn: September–November; winter: December–February), age group (young: 18–39 years; middle-aged: 40–59 years; elderly: ≥60 years), altitude category (<500 m, 500–1000 m, 1000–2000 m, ≥2000 m) and disease type (stroke, acute myocardial infarction (AMI), angina pectoris, sudden cardiac death (SCD)).

2.4. Outcome Definitions

All CVD cases were diagnosed in accordance with internationally established clinical diagnostic criteria for stroke, AMI, angina pectoris and SCD.

Crude incidence rate: Number of new-onset CVD cases per 100,000 population during the study period.

Age-standardized incidence rate (ASIR): Calculated by the direct standardization method using the population structure of the Seventh National Population Census as the reference.

Survival proportion: (Number of survivors after disease onset/Total number of incident cases) × 100%.

2.5. Statistical Analysis

All statistical analyses were performed using R software (version 4.6.0). A two-sided p value < 0.05 was considered statistically significant. Descriptive statistics were used to summarize the general characteristics of the study population. Crude incidence rates, age-standardized incidence rate (ASIR) and survival proportions were calculated and stratified by year, province, gender, age group, season, altitude and disease subtype.

Global Moran's I statistic was applied to evaluate spatial autocorrelation and characterize the spatial distribution pattern (clustered, dispersed or random) of CVD incidence. A generalized linear model (GLM) was constructed to explore independent factors associated with CVD incidence, including year, gender, age stratum, season, disease type and altitude. Adjusted estimates, standard errors, z values and corresponding *p* values were reported for each variable.

3. Results

3.1. General Characteristics

Table 1 summarizes the overall patterns of CVD incidence across four provinces in western China from 2023 to 2024. The overall ASIR across the provinces decreased from 600.21 per 100,000 in 2023 to 531.92 per 100,000 in 2024. Geographic variation was observed, with Yunnan reporting the highest ASIR in 2024 (686.46 per 100,000), whereas Qinghai consistently exhibited the lowest survival proportion, declining further to 64.96% in 2024. From 2023 to 2024, the ASIRs decreased in Sichuan, Qinghai, and Yunnan, while an increase was observed in Guizhou.

Gender-stratified analysis indicated that males consistently had higher ASIRs than females, whereas survival proportions were comparable between sexes, remaining within 83–85%. Over the study period, incidence declined in both sexes.

Disease-specific analysis showed that stroke accounted for the largest proportion of CVD burden, followed by acute myocardial infarction (AMI) and angina pectoris. Sudden cardiac death (SCD), although relatively rare, exhibited a markedly low survival proportion (all below 2.5%), reflecting its high fatality. Incidence of stroke and AMI declined in 2024, whereas slight increases were observed for angina pectoris and SCD.

Age-stratified analysis revealed an increasing trend in incidence with advancing age, with the elderly group exhibiting substantially higher rates than younger and middle-aged groups. Incidence decreased across all age groups over the study period.

Seasonal analysis indicated relatively higher ASIRs in spring and winter, and lower levels in summer and autumn, with a general decreasing trend over time.

Altitude-stratified analysis suggested higher ASIR in low-altitude areas, whereas populations residing at ≥2000 m had lower survival proportions compared to other strata. During the study period, ASIR increased only in the 1000–2000 m altitude group, while declines were observed in all other altitude categories.

Table 1. Overall characteristics of cardiovascular disease incidence in four provinces.

Characteristics	2023			2024		
	Incidence Rate (per 100,000)	**Survival Proportion (%)**	**ASIR (per 100,000)**	**Incidence Rate (per 100,000)**	**Survival Proportion (%)**	**ASIR (per 100,000)**
Province						
Guizhou	338.51	97.04	357.40	396.27	97.79	391.43
Qinghai	452.38	70.23	547.21	425.67	64.96	514.87
Sichuan	690.84	84.15	627.73	596.37	82.04	528.53
Yunnan	536.53	81.97	639.82	474.68	81.94	686.46
Gender						
Male	706.21	84.09	657.36	604.99	83.05	588.87
Female	562.86	84.75	540.26	477.05	83.06	472.23
Diagnosis						
AMI	84.82	64.99	80.19	69.11	61.67	67.83
Angina Pectoris	35.82	98.76	34.35	35.75	99.33	35.56
Stroke	508.16	87.62	479.76	430.73	86.33	422.27
SCD	6.32	1.96	5.92	6.38	2.49	6.27
Age Stratum						
Young	16.76	80.89	18.15	16.13	81.20	17.51
Middle-aged	276.67	89.97	277.87	240.99	88.56	244.10
Elderly	2132.04	83.24	2048.69	1885.11	81.90	1816.84
Season						
Spring	178.38	86.03	168.49	142.49	83.15	139.90
Summer	152.69	87.12	144.49	132.93	84.20	130.50
Autumn	138.51	86.20	131.00	124.16	85.66	121.93
Winter	165.54	78.54	156.24	142.39	79.60	139.60
Altitude (m)						
<500	740.27	82.21	612.37	671.44	81.32	534.56
500–1000	538.37	92.69	648.48	404.24	90.57	470.28
1000–2000	466.19	84.34	488.56	475.48	83.02	582.25
≥2000	452.38	70.23	547.21	425.67	64.96	514.87
Total	635.12	84.38	600.21	541.96	83.05	531.92

Note: Survival proportion (%) = Number of survivors after onset/Total number of incident cases × 100%. Age-standardized incidence rate was calculated based on the population data from the 7th National Population Census of the People's Republic of China. Values of Incidence rate and age-standardized incidence rate were per 100,000. Young: 18–39 years; Middle-aged: 40–59 years; Elderly: ≥60 years. Spring (March–May), Summer (June–August), Autumn (September–November), Winter (December–February). Abbreviations: ASIR, age-standardized incidence rate; AMI, acute myocardial infarction; SCD, Sudden Cardiac Death.

3.2. Altitudinal Distribution

Figure 1 illustrates the association between altitude and the incidence of different types of CVDs in four provinces of western China from 2023 to 2024. In Figure 1A, stroke showed the highest incidence across all altitude strata, with the highest value observed in the <500 m group (556.8 per 100,000), followed by a gradual decrease at higher altitudes. AMI and angina pectoris exhibited relatively stable incidence levels across altitude categories, with higher values observed in the 1000–2000 m group (90.6 and 40.8 per 100,000, respectively) and the ≥2000 m group (89.8 and 40.4 per 100,000, respectively). SCD had the lowest incidence across all altitude strata, ranging from 6.7 per 100,000 in the 500–1000 m group to 10.5 per 100,000 in the 1000–2000 m group.

Figure 1B presents the relationship between altitude and incidence rates for each disease. Stroke incidence decreased with increasing altitude ($\beta = -0.36$, $p < 0.01$). AMI showed a relatively stable distribution with a slight increase at higher altitudes, although no statistically significant trend was observed. Angina pectoris and SCD remained at low incidence levels across the altitude range, with no clear trend observed.

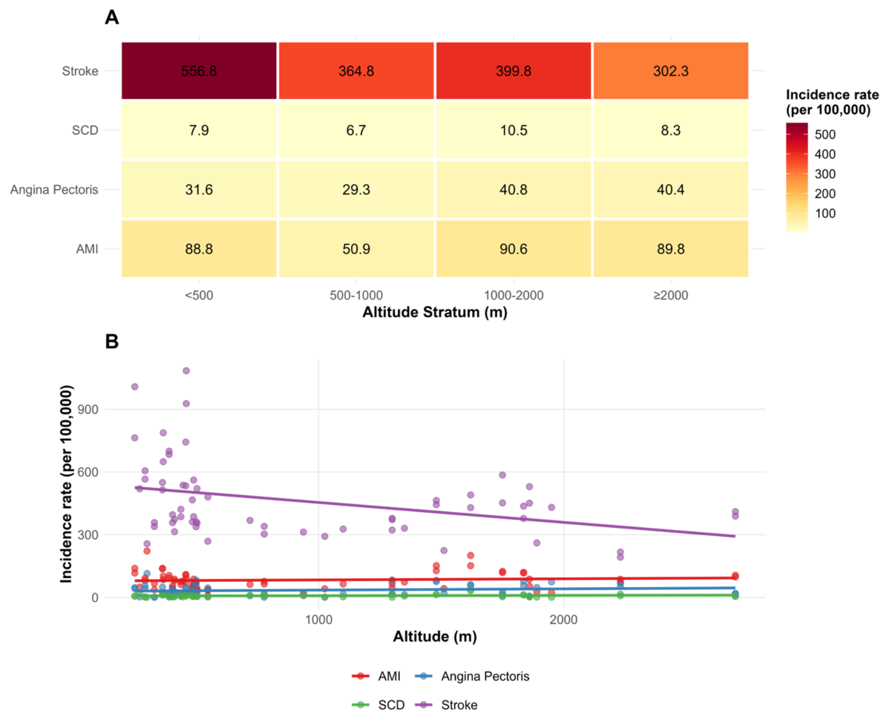

Figure 1. Association between altitude and the incidence of CVD in four provinces of western China from 2023 to 2024. (**A**) Heatmap of associations between different altitudes and CVD incidence. (**B**) Scatter plot of correlation between altitude and CVD incidence, each point in the scatter plot represents the average level of the surveyed counties.

3.3. Temporal Distribution

Figure 2 presents the temporal and seasonal patterns of CVD incidence in four provinces of western China from 2023 to 2024. Figure 2A shows the monthly trends, with overall incidence levels gradually declining from January to December. Higher incidence levels were observed at the beginning of the year, followed by a general decrease over the course of the year.

Figure 2B illustrate the seasonal distribution of CVD. AMI showed a pattern similar to stroke, with higher incidence levels in spring and winter compared to summer and autumn. Angina pectoris exhibited relatively stable incidence across seasons, with minimal variation. SCD remained at low incidence levels throughout all seasons, with slightly higher values observed in winter.

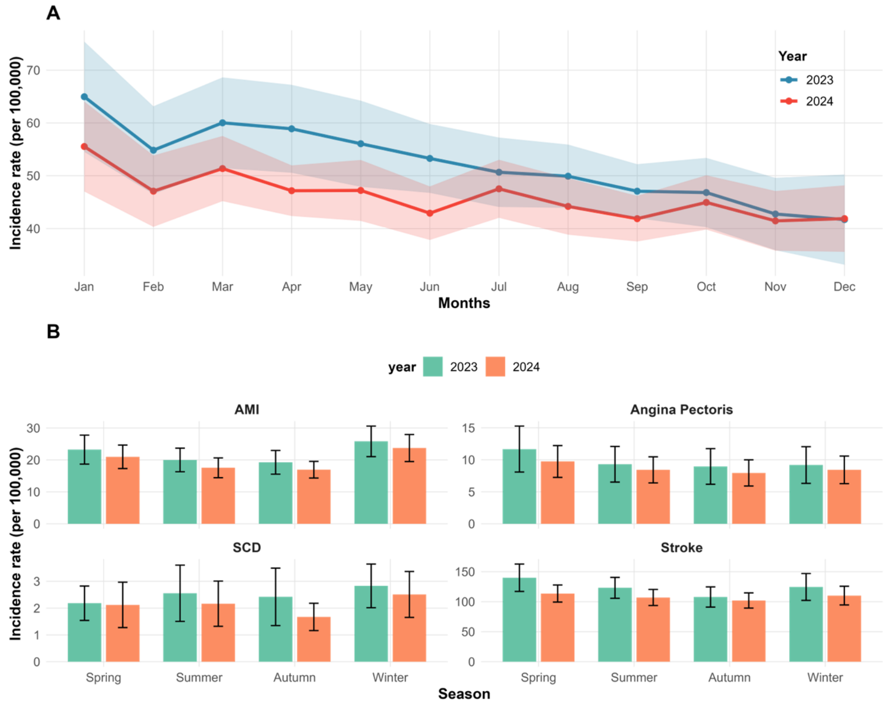

Figure 2. Monthly and seasonal distribution of CVD incidence in four provinces of western China from 2023 to 2024. (**A**) Monthly distribution. The shaded area represents the 95% confidence interval. (**B**) Seasonal distribution. Spring (March–May), Summer (June–August), Autumn (September–November), Winter (December–February).

3.4. Spatial Distribution

The global Moran's I indices for spatial autocorrelation of the four cardiovascular and cerebrovascular diseases—acute myocardial infarction (Figure 3A), angina pectoris (Figure 3B), stroke (Figure 3C), and sudden cardiac death (Figure 3D)—were 0.06, 0.04, 0.05, and −0.11, respectively (all *p*-values > 0.05), indicating that the spatial distribution of the incidence of these diseases in the study area approximated a random pattern.

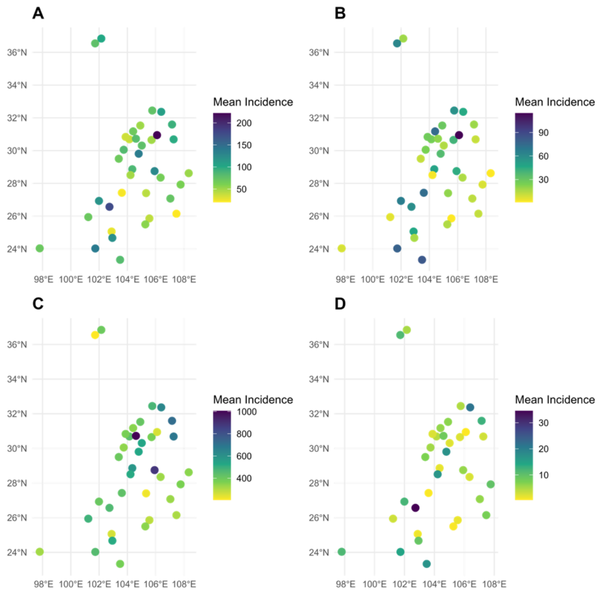

Figure 3. Spatial heatmaps of cardiovascular disease incidence in four western provinces. (**A**) AMI (**B**) Angina pectoris. (**C**) Stroke. (**D**) SCD.

3.5. Multivariate Regression

Table 2 presents the regression results for factors associated with CVD incidence. No clear difference was observed between 2023 and 2024. Males had higher incidence levels than females (p < 0.001). Age was an important factor associated with incidence. Compared with the elderly group, both middle-aged and young populations had lower incidence levels (both $p < 0.001$). Incidence levels were relatively consistent across seasons, with no statistically significant differences observed.

In terms of disease types, compared with AMI, angina pectoris and SCD were associated with lower incidence levels ($p = 0.018$ and $p < 0.001$, respectively), whereas stroke showed higher incidence levels ($p < 0.001$). No clear association was observed between altitude and CVD incidence across different altitude strata.

Table 2. Factor effects of cardiovascular disease incidence using generalized linear model.

Factors	Estimate	Standard Error	z Value	Pr (>|z|)
Intercept	95.426	10.451	9.130	<0.001 ***
Year (ref = 2023)				
2024	−4.462	5.703	−0.782	0.434
Gender (ref = Female)				
Male	20.560	5.752	3.575	<0.001 ***
Age Stratum (ref = Elderly)				
Middle-aged	−109.241	6.643	−16.445	<0.001 ***
Young	−138.420	7.365	−18.793	<0.001 ***
Season (ref = Autumn)				
Spring	13.789	8.043	1.714	0.089
Summer	7.338	8.102	0.906	0.366
Winter	8.218	8.068	1.019	0.309
Diagnosis (ref = AMI)				
Angina Pectoris	−19.105	8.065	−2.369	0.018 *
Stroke	120.045	7.736	15.518	<0.001 ***
SCD	−36.747	8.300	−4.427	<0.001 ***
Altitude (m) (ref = <500 m)				
500–1000	−3.428	7.881	−0.435	0.664
1000–2000	−4.593	7.815	−0.588	0.557
≥2000	−16.017	8.421	−1.902	0.058

Note: * $p < 0.05$, *** $p < 0.001$.

4. Discussion

This study systematically assessed CVD incidence in western China across multiple dimensions, including geography, time, population characteristics, and altitude. Between 2023 and 2024, CVD incidence in Yunnan province was consistently higher than in the other three provinces. Notably, although CVD incidence in Qinghai was relatively low, survival rates were the lowest, likely reflecting limitations in local healthcare resources. During the same period, CVD incidence decreased to varying degrees in Sichuan, Yunnan, and Qinghai, whereas incidence in Guizhou increased. These findings indicate substantial provincial variation in CVD incidence, underscoring the need for local health authorities to develop targeted prevention and control strategies tailored to regional conditions.

From a disease-specific perspective, stroke was the predominant contributor to the overall CVD burden. This finding is consistent with previous epidemiological studies in China [5,12], and may be related to the currently low rates of hypertension and lipid control in China, as well as shifts in dietary patterns [13–16]. However, compared with many high-income Western countries, stroke appears to account for a relatively greater proportion of the CVD burden in China [17,18]. This difference may reflect variations in the stage of epidemiological transition, healthcare systems, and the long-term management strategies for cardiovascular risk factors across populations [19]. Given the substantial contribution of stroke to the CVD burden observed in our study, strengthening stroke prevention through improved awareness and comprehensive management of modifiable risk factors may help reduce the overall CVD burden.

Sex differences in CVD incidence were evident in this study, with males consistently exhibiting higher incidence than females. This finding aligns with previous research from China and other countries [5,6,18], and the difference may partly reflect sex-related differences in biological characteristics and exposure to behavioral and lifestyle risk factors [20]. In contrast, survival rates were comparable between sexes, suggesting that sex differences are more pronounced in disease occurrence rather than in outcomes. In addition, CVD incidence increased markedly with age, reflecting a clear age gradient. This pattern is consistent with classical cardiovascular epidemiology and highlights the need for targeted prevention and management strategies in aging populations [21,22].

Seasonal variation was also observed, with higher CVD incidence in spring and winter, especially in winter. This pattern is consistent with previous epidemiological studies [23], the increased cardiovascular risk induced by cold is generally associated with changes in the autonomic nervous system, elevated blood pressure, enhanced blood coagulation, inflammatory responses, and oxidative stress [24]. Therefore, comprehensive measures including health education, high-risk population management and community support should be implemented to reduce the risk of cardiovascular events during cold seasons.

In addition, analysis of Global Moran's I in our study indicated that no significant global spatial autocorrelation was observed for county-level CVD incidence. This suggests that, at the county level, geographic proximity is not a primary determinant of CVD risk, and local variations are likely driven more by population characteristics, lifestyle behaviors, environmental exposures and healthcare accessibility than by purely spatial factors.

The association between altitude and CVD incidence was more complex. Previous studies have suggested that chronic hypoxia at high altitude may impose additional cardiovascular strain [25,26]. However, this contrasts with our univariate analysis, which indicated a negative correlation between stroke incidence and altitude. Interestingly, our multivariable analysis did not reveal a clear independent association between altitude and CVD incidence. Some studies also suggest that populations living at high altitude may engage in more physical activity, consume healthier diets, lower obesity rates, and adapt to mild hypoxia, potentially conferring cardiovascular protection [27,28]. Moreover, one study has reported that altitude may influence CVD risk differently across populations of varying ethnic backgrounds [29]. Taken together, these findings suggest that the impact of altitude on CVD incidence is likely mediated by a combination of healthcare accessibility, population structure, and socioeconomic factors, highlighting the need for further large-scale epidemiological studies to clarify this relationship.

Limitations of the Study

This study has several limitations. First, although the study included four western provinces of China, the vast geographical and environmental heterogeneity of the western region means that caution should be exercised when extrapolating our results to the broader western region of China. Second, due to limitations in data availability, this study was unable to fully account for potential influencing factors, including climate, healthcare resources, population structure, and lifestyle across provinces. Further comprehensive and finer-scale studies are needed to further validate our findings. Finally, the relatively short study period (2023–2024) may not adequately capture long-term trends in CVD incidence.

5. Conclusions

In conclusion, CVD incidence in western China varies across geographic, temporal, demographic, and environmental factors, with stroke remaining the primary contributor to the overall burden. Incidence is higher among males and older individuals, with seasonal peaks in spring and winter. Although descriptive analyses suggested absolute differences across altitude strata, multivariable analysis did not reveal an independent association between altitude and CVD incidence. These findings highlight the need for targeted public health interventions, including prevention strategies for high-risk populations, seasonal risk management, and strengthened primary healthcare services in resource-limited areas.

Author Contributions

Z.W. (Zengwu Wang) and B.Z.: conceptualization, methodology, software; Z.W. (Zhuo Wang), Q.R. and C.Z.: data curation, writing—original draft preparation; X.W., X.P., Y.H., Q.J., Y.Z., X.Q., Y.L. and R.H.: visualization, investigation; K.J.: supervision; Z.W. (Zhuo Wang) and C.Z.: software, validation; Z.W. (Zengwu Wang) and B.Z.: writing—reviewing and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This study was funded by National Major Science and Technology Project, Research on Innovation and Application Demonstration of Chronic Disease Prevention and Treatment Technology Promotion Mechanism, grant number 2024ZD0523905; National Science and Technology Major Project, Research and Application Demonstration of Promotion Mechanism of Major Chronic Disease Prevention and Treatment Technology, grant number 2024ZD0523900.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

Acknowledgments

We extend our sincere gratitude to all teams engaged in cardiovascular disease surveillance efforts across China for their dedication and contributions.

Conflicts of Interest

Given the role as Associate Editor, Zengwu Wang had no involvement in the peer review of this paper and had no access to information regarding its peer-review process. Full responsibility for the editorial process of this paper was delegated to another editor of the journal. The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

The authors employed Deepseek during manuscript preparation to improve language clarity, readability, and overall structure for journal submission. After using this service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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