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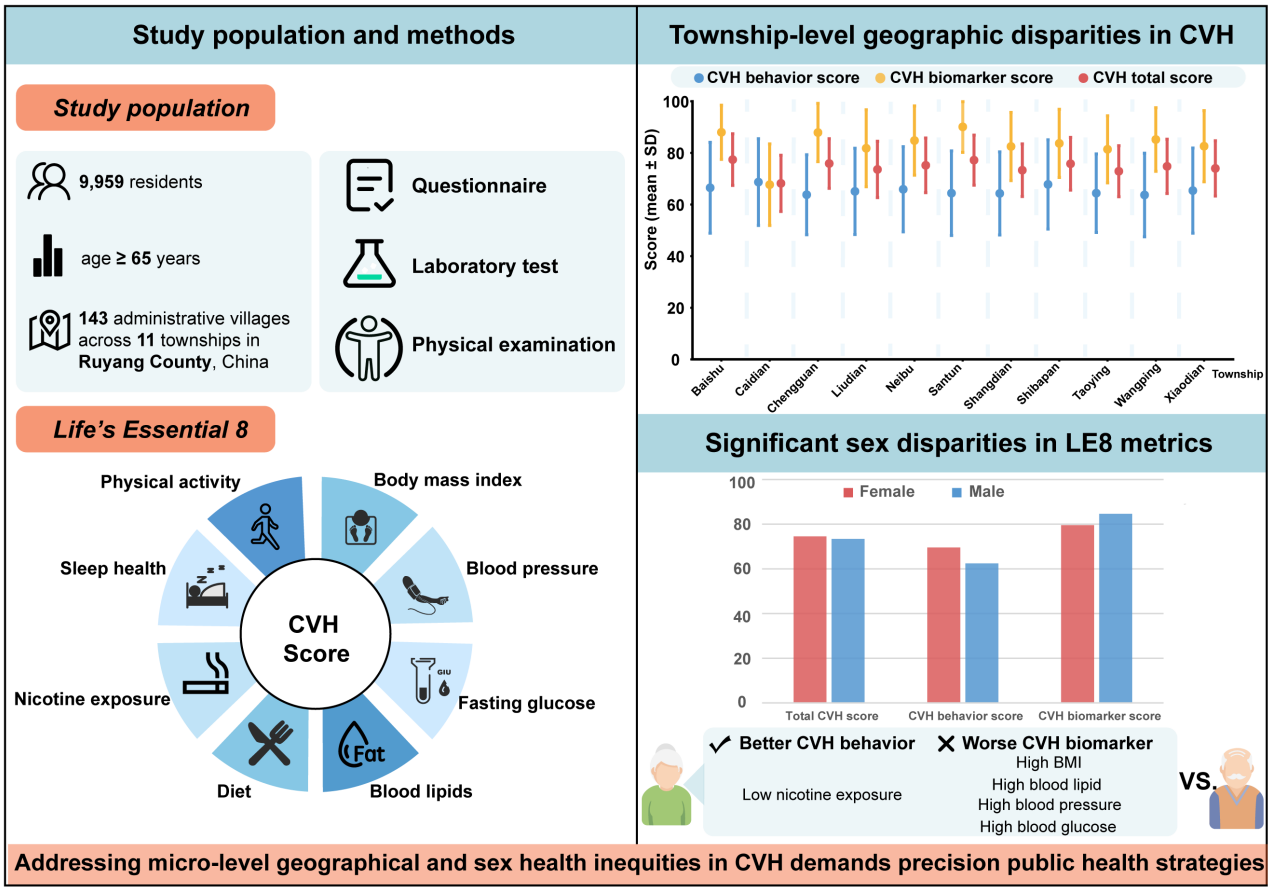
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Township-level geographic and sex disparities of cardiovascular health among elderly population

A cross-sectional study in rural China

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Graphical abstract



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Abstract

Background: Despite considerable evidence regarding macro-region-level disparities in cardiovascular health (CVH), a critical knowledge gap regarding the finer-scale spatial heterogeneity of CVH at the township level still exists. There is a need to precisely depict micro-level geographic and sex-based CVH disparities to guide targeted health policies.

Methods: In 2022, we recruited 9,959 residents aged ≥ 65 years from 143 administrative villages across 11 townships in Ruyang County, China. CVH status was assessed using life's essential 8 (LE8) metrics—diet, physical activity, smoking, sleep quality, body mass index, blood pressure, lipids, and fasting glucose—through questionnaires and physical examinations.

Results: Participants had a mean (standard deviation, SD) age of 71 (7.18) years, with 5,577 (56%) being female. Among behavioral components, diet and physical activity demonstrated the lowest adherence to ideal CVH, whereas blood pressure was the least optimal biomarker metric. Significant geographic variations in CVH were observed across 11 townships in Ruyang County. Industrialized townships, especially Caidian, demonstrated elevated cardiometabolic risks. Female participants exhibited superior behavioral scores, particularly in nicotine avoidance, but inferior biomarker profiles, including higher body mass index, fasting glucose, and cholesterol levels. Sex disparities in CVH status varied by township, with urbanized areas (Chengguan) exhibiting less pronounced sex disparities.

Conclusion: This study underscores the micro-level geographical and sex health inequities among the elderly population. Addressing these disparities demands precision public health strategies that account for both geospatial heterogeneity and gender-specific risk profiles. These findings offer a framework for mitigating CVH disparities in other developing regions globally.

Keywords: cardiovascular health, geographic disparity, sex difference, socioeconomic transition

Nonstandard Abbreviations and Acronyms:

AHA =	American Heart Association,
BMI =	body mass index,
CVD =	cardiovascular disease,
CVH =	cardiovascular health,
DASH =	Dietary Approaches to Stop Hypertension,
FBG =	fasting blood glucose,
GBD =	Global Burden of Disease,
HDL =	high-density lipoprotein,
LDL =	low-density lipoprotein,
LE8 =	Life's Essential 8,
SBP =	systolic blood pressure,
SD =	standard deviation,
TC =	total cholesterol,
TG =	triglyceride.

Highlights

- Despite global efforts to fight for health equity, substantial geographic and sex disparities in cardiovascular health still exist on multiple scales.
- In this cross-sectional study that included 9,959 participants from 143 administrative villages across 11 townships in Ruyang County, the cardiovascular health of the elderly population presented with township-specific phenotypes.
- Females had a worse performance in cardiovascular health biomarker metrics, despite their advantage in cardiovascular health behavior metrics over males.
- Significant geographic and sex differences observed in Ruyang County suggested the need for targeted health interventions for regions currently undergoing socioeconomic transition.

1. Introduction

Cardiovascular diseases (CVDs) remain the leading cause of global mortality, with disproportionately high burdens observed in developing nations undergoing rapid socioeconomic transition.[1] In recent decades, China's rapid economic growth has dramatically altered lifestyles. To prevent this economic progress from increasing the risk of lifestyle-related diseases, it is essential to implement effective public health strategies and promote healthy living practices. Existing epidemiological studies have primarily focused on provincial-level or larger regions (such as northern vs. southern China and rural vs. urban areas) disparities in cardiovascular health (CVH).[2,3] Recent attention has shifted toward examining these variations at smaller, more specific levels, emphasizing a critical knowledge gap regarding the finer-scale spatial heterogeneity of CVH at the township level.[4,5] Detailed analysis of CVH at a finer spatial resolution, such as the township level, can uncover disparities in health outcomes and risk factors that broader data might obscure.

Despite a global decline in age-standardized cardiovascular disease mortality for the past 3 decades among women, this reduction has been largely attributed to countries with a high sociodemographic index.[6,7] In contrast, data from the global burden of disease study show that in countries with a low sociodemographic index, the highest cardiovascular disease mortality rates have shifted from men to women.[6,7] Moreover, evidence suggests that women receive less treatment than men in both primary and secondary CVD prevention, especially within underrepresented sociodemographic groups.[8–10] These findings underscore the importance of examining sex-specific CVH patterns in the rural elderly population to enhance targeted prevention strategies.

Ruyang County, situated in central China, encompasses a rural area of 1,332 km^2 with a population of 430,000. Its diverse landform includes plains in the north and mountainous terrain in the south. The economic development varies among townships, with differences in agriculture, manufacturing, and service industries. This presents a unique opportunity to study the prevalence and characteristics of CVH metrics in a developing township in China. This study, conducted in Ruyang, aims to assess geographic variations in CVH status at the township level and explore gender differences in CVH across different geographic scales.

2. Methods

2.1. Participants and procedure

The public health checkup program was part of a chronic disease screening program organized by the Ruyang County People's Government. All residents aged ≥ 65 years in Ruyang County were invited to participate in an annual health checkup at township-level health centers. Medical staff from the Ruyang County People's Hospital were responsible for collecting participants' demographic data, health questionnaire responses, and performing specialized cardiovascular disease screenings and laboratory tests. The checkup data were organized and stored by the Ruyang Health Commission. All personal information was anonymized in accordance with data security and confidentiality protocols.

There were a total of 54,942 residents aged ≥ 65 years from 11 surveyed townships (195 administrative villages) in Ruyang County, all of whom were invited to participate in the government-organized public health checkup program. Of these, 38,306 residents from 187 villages participated in the government-organized health checkup, which corresponds to an initial response rate of 69.7%. To ensure the validity of the study, 9,959 participants from 143 villages who completed all components of the health checkup—questionnaire, physical examination, and laboratory tests—were included in the final analysis, yielding a final inclusion rate of 18.1% (Figure S1, Supplemental Digital Content, https://links.lww.com/CARES/A17).

This study utilized publicly available data from the chronic disease screening program conducted between July and September 2022 for analysis. Researchers did not have access to any identifiable personal information. The ethics committee waived the ethical review of this study as a derivative data analysis of the completed public screening program.

2.2. Measurement

Demographic and health information, including history of diabetes, hypertension, or coronary heart disease, as well as relevant medication history, was collected to evaluate life's essential 8 (LE8) metrics. These metrics, proposed by the American Heart Association (AHA), are used for the primary prevention of CVDs.[11] Questionnaires were used to gather data on behavior metrics, including dietary habits, physical activity, sleep patterns, and nicotine/tobacco product exposure. The 25-item food frequency questionnaire assessed diet patterns by recalling and reporting the frequency of 25 food items consumed over the previous week. The alcohol use disorders identification test measured daily alcohol consumption. The International Physical Activity Questionnaire Short Form Chinese version quantified the weekly duration of moderate and high-intensity physical activities. The Pittsburgh Sleep Quality Index evaluated sleep quality and daily average sleep duration based on 11 items. Smoking amount and history were assessed using the adjusted Fagerström test for nicotine dependence .

The physical examination and laboratory tests measured key CVH biomarkers, including body mass index (BMI), fasting blood glucose levels (FBGs), systolic blood pressure (SBP), and non-high-density lipoprotein (non-HDL) cholesterol levels. The survey protocol was designed by the Ruyang Rural Health Institution Academic Committee and approved by the Ruyang County Health Administration.

2.3. CVH metrics

We standardized original CVH indicators into LE8 metrics based on the latest AHA algorithm (Table S1, Supplemental Digital Content, https://links.lww.com/CARES/A17).[11] For diet and physical activity assessment, we adapted the original AHA algorithm to better fit our population. Specifically, we used the dietary approaches to stop hypertension diet pattern to evaluate dietary habits, categorizing 25 items into six food groups: whole grains, vegetables and fruits, dairy products, fats, lean meats, and added sugars. Adherence was evaluated with a score above six indicating compliance with daily consumption requirements. Physical activity was assessed by calculating the weekly duration of exercise, with days of moderate and high-intensity activities over half an hour weighted by intensity. In the sensitivity analysis, we applied Chinese-specific thresholds for BMI to reassign the LE8 BMI score.

Each participant's total CVH score was calculated by averaging the 8 LE8 component metrics. Additionally, we computed two separate scores: the CVH behavior score, which is the average of scores for diet, physical activity, nicotine exposure, and sleep; and the CVH biomarker score, which is the average of scores for BMI, blood lipids, blood glucose, and blood pressure. Ideal rates for CVH metrics were defined as the proportion of participants achieving a perfect score of 100 in each LE8 component. Age- and sex-standardized ideal rates were then calculated using the overall surveyed population as the reference.

2.4. Statistical analysis

Categorical variables were summarized as proportions, and continuous variables were reported as mean (standard deviation, SD). Baseline characteristics were summarized by sex, and differences were compared using the χ^2

test for categorical variables and the unpaired *t* test for continuous variables.

To investigate CVH geographical disparity, we described the SD of LE8 metrics by townships. We also displayed the distribution of four CVH biomarker values (BMI, non-HDL, fasting glucose, and SBP) in each township using a density plot. An analysis of variance test was used to compare LE8 scores and four CVH biomarker values between townships. A Bonferroni correction was applied to account for the 11 comparisons across CVH metrics. Age- and sex-standardized ideal rates with 95% confidence intervals (CIs) of CVH indicators were also presented by townships and compared using the χ^2 test.

To evaluate sex differences, we calculated the sex difference of LE8 metrics with males as the reference and made comparisons between females and males using a *t* test in each township. Age-adjusted logistic models were applied to evaluate the association between sex and CVH ideal rates in townships, displayed by forest plots. To explore factors associated with CVH metrics, we further constructed multivariable linear regression models incorporating age, sex, education, marital status, and occupation variables.

The data were accessed and analyzed from August 8, 2023, to July 1, 2024. In the analysis, only participants with complete CVH metrics data were included, and there were no missing values for the CVH variables. All tests were 2-sided with a significance level of $p < 0.05$. Analyses were conducted using the statistical analysis system 9.4 software, and figures were generated using R software (version 4.2.0).

3. Results

3.1. Characteristics of the study population

We included 9,959 participants from 143 administrative villages across 11 townships in Ruyang County, with sample sizes ranging from 203 (Wangping) to 2,027 (Caidian), as shown in Table S2, Supplemental Digital Content, https://links.lww.com/CARES/A17. Demographic characteristics and LE8 components by gender are detailed in Table 1. The average age of participants was 71 years, with 5,577 (56.0%) females. Women were more likely to be illiterate compared with men (69.4% vs. 35.0%) and had a higher proportion of widowed status (20.5% vs. 11.9%). Figure 1 displays the density distribution of BMI, SBP, non-HDL cholesterol, and FBGs. Approximately one-third of the population was classified as overweight, two-thirds had suboptimal blood pressure, and the majority had optimal fasting blood glucose levels. Non-HDL cholesterol levels varied significantly by township ($p < 0.001$), with Caidian—an area known for its liquor production—exhibiting a distribution notably skewed to the right of the normal cutoff. Additionally, women had higher levels of BMI, SBP, FBGs, and lipid components (Table 1).

3.2. Spatial pattern

Among all participants, the mean scores were as follows: total CVH score was 73.4, behavior score was 65.8, and biomarker score was 81.2. Diet (mean score: 49.7) and physical activity (mean score: 42.2) were identified as the most notable suboptimal behaviors, whereas blood pressure (mean score: 69.4) was the least satisfactory biomarker metric.

Significant variations ($p < 0.001$) in overall CVH status (Fig. 2) and specific components, including lipid levels, physical activity, and blood pressure, were observed at the township level (Table S3, Supplemental Digital Content, https://links.lww.com/CARES/A17). The differences in CVH metrics across townships remained significant after Bonferroni correction. Caidian township reported the lowest scores for total CVH (mean score: 68.2), blood lipids (mean score: 35.5), and blood pressure (mean score: 61.6). In the sensitivity analysis using Chinese-specific BMI thresholds, the mean reassigned BMI score increased slightly across townships (Table S4, Supplemental Digital Content, https://links.lww.com/CARES/A17).

Total and behavioral CVH scores decreased with advancing age across all townships (Table S5, Supplemental Digital Content, https://links.lww.com/CARES/A17). Different age-related patterns in CVH biomarker scores were observed in different townships (Table S5, Supplemental Digital Content, https://links.lww.com/CARES/A17). The mean CVH biomarker score increased from 66.2 points in the group aged 65 to 75 years to 70.8 points in the group aged ≥ 80 years. Townships (e.g., Baishu, Santun) remained relatively stable across age groups.

Ideal CVH status across all LE8 components was exceedingly rare, achieved by only 9 participants (< 0.1%). Poor overall CVH was associated with low ideal rates in diet (5%) and physical activity (39%). Age- and sex-standardized ideal rates for CVH components varied significantly between townships ($p < 0.001$; Table 2). The spatial distribution of ideal blood lipid (14%). and blood pressure levels (37%) revealed Caidian as a hotspot for uncontrolled cardiometabolic risk factors.

3.3. Gender disparity

Overall, females had a CVH total score that was 1.2 points higher than males (95% CI: 0.7, 1.6). However, gender disparities in CVH behaviors and biomarkers showed contrasting trends. Females had a 7.1-point advantage in health behaviors (95% CI: 6.5, 7.8), which was largely due to a higher nicotine exposure score (35.2, 95% CI: 33.9, 36.5). Conversely, women scored 5.1 points lower in CVH biomarker metrics (95% CI: 4.4, 5.7) and exhibited poorer results across four individual biomarker components.

Figure 3 illustrates the gender differences in CVH metric scores across surveyed townships (Table S6, Supplemental Digital Content, https://links.lww.com/CARES/A17). Females consistently performed worse in

Table 1

Demographic characteristics.

Characteristic	Female (n = 5,577)	Male (n = 4,382)	p Value
Age, year	70.7 (7.5)	71.4 (6.7)	< 0.001
Marital status			< 0.001
Married	4,358 (78.4)	3,702 (84.5)	
Widowed	1,140 (20.5)	521 (11.9)	
Unmarried/separated/divorced	59 (1.1)	159 (3.6)	
Occupation			0.333
Agriculture	4,545 (81.5)	3,532 (80.7)	
Education level			< 0.001
Illiterate	3,872 (69.4)	1,533 (35.0)	
Primary school	1,253 (22.5)	1,515 (34.6)	
Middle school	338 (6.1)	992 (22.6)	
High school	106 (1.9)	306 (7.0)	
College or university	8 (0.1)	36 (0.8)	
Self-reported disease history			
Hypertension	3,632 (65.1)	2,256 (51.5)	< 0.001
Diabetes	1,204 (21.6)	562 (12.8)	< 0.001
Coronary heart disease	520 (9.3)	395 (9.0)	0.595
Body mass index, kg/m^2	24.1 (3.5)	23.3 (3.0)	< 0.001
Systolic blood pressure, mmHg	137.3 (19.0)	133.2(17.5)	< 0.001
Fasting blood glucose, mmol/L	5.4 (2.0)	5.1 (1.8)	< 0.001
Total cholesterol, mmol/L	5.0 (1.5)	4.6 (1.3)	< 0.001
Non-HDL cholesterol, mmol/L	3.4 (1.5)	3.0 (1.4)	< 0.001
Triglyceride, mmol/L	1.8 (1.2)	1.4 (1.2)	< 0.001
LDL cholesterol, mmol/L	2.4 (0.8)	2.2 (0.7)	< 0.001
AHA life's essential 8 score			
Total CVH score	73.9(10.7)	72.8 (10.9)	< 0.001
CVH behavior score	68.9 (14.9)	61.8 (17.6)	< 0.001
CVH biomarker score	78.9 (15.9)	84 (14.0)	< 0.001
Dietary score	49.9 (23.0)	49.4 (23.2)	0.247
Physical activity score	39.3 (47.6)	45.9 (48.5)	< 0.001
Nicotine exposure score	98.9(10.0)	63.7 (46.7)	< 0.001
Sleep health score	86.4 (21.7)	87.2 (20.9)	0.056
Body mass index score	87.4 (19.4)	91.3 (15.9)	< 0.001
Blood lipid score	72.0 (34.1)	81.6 (29.7)	< 0.001
Blood glucose score	87.5 (25.5)	92.8 (19.3)	< 0.001
Blood pressure score	68.8 (30.6)	70.1 (29.9)	0.039

Data are presented as n (%) for categorical variables or mean (SD) for continuous variables.
AHA = American Heart Association; CVH = cardiovascular health; SD = standard deviation.

CVH biomarkers, including BMI, blood lipid, and glucose, in each township. Tobacco use was the only CVH parameter for which females scored higher than males. Patterns for diet and sleep health were similar between genders across townships. Figure S2, Supplemental Digital Content, https://links.lww.com/CARES/A17 shows comparable sex disparities in age-standardized ideal CVH rates across townships.

Total CVH scores decreased with age in both sexes (Table S7, Supplemental Digital Content, https://links.lww.com/CARES/A17). Females had higher CVH behavior scores and males had higher CVH biomarker scores, with both sex differences narrowing with advancing age (Table S7, Supplemental Digital Content, https://links.lww.com/CARES/A17). The CVH behavior score gap between females and males fell from 8.45 (95% CI: 7.46, 9.43) in the group aged 65 to 75 years to 3.15 (95% CI: 1.41, 4.88) in the group aged ≥ 80 years, while the CVH biomarker gap narrowed from −5.93 (95% CI: −6.85, −5.01) to −2.78 (95% CI: −4.51, −1.05).

3.4. Factors associated with CVH status

In multivariable linear models, both being female and having an education level of middle school or higher were independently associated with a higher CVH behavior score but a lower CVH biomarker score (Table 3). Additionally, nonmarried status and holding a nonagricultural occupation were associated with a lower CVH behavior score (Table 3).

4. Discussion

In this population-based cross-sectional survey conducted in 2022 across 11 townships in Ruyang County, we observed that ideal CVH status was extremely rare and substantial geographic variations in CVH status as measured by the LE8 metrics. Notably, sex disparities in CVH metrics also displayed regional characteristics, with females generally performing worse in CVH biomarkers such as BMI, blood lipids, and glucose while scoring higher in tobacco use compared with males. These contemporary findings underscore the impact of rapid

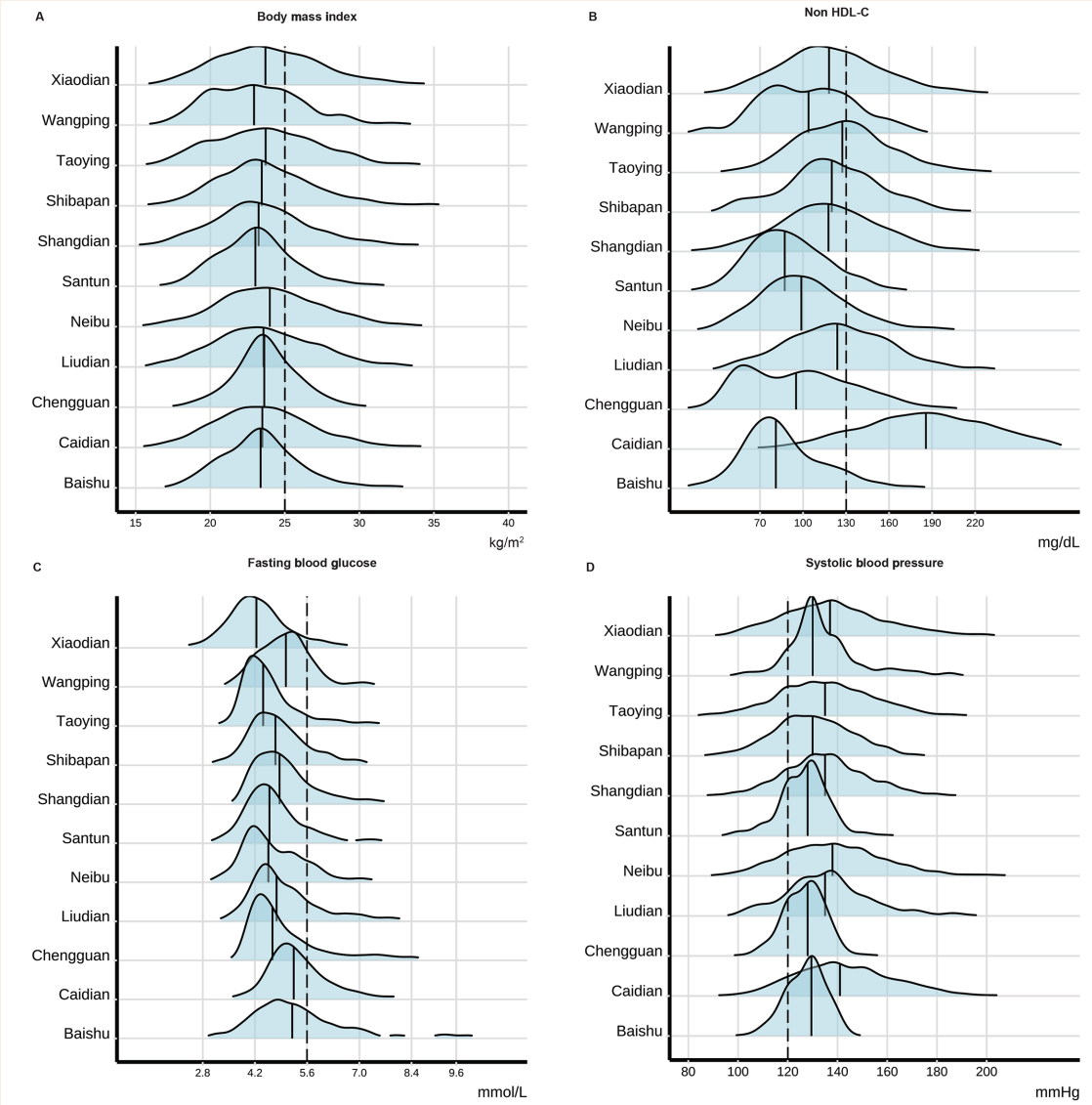


Figure 1. Density plots of four CVH biomarker values by 11 townships in Ruyang. Density plots of body mass index (A), non-HDL-C (B), fasting blood glucose (C), and systolic blood pressure (D) by 11 townships in Ruyang The dashed line indicates the ideal cutoff per the Life's Essential 8 algorithm. CVH = cardiovascular health.

socioeconomic changes on health patterns and highlight the need for equity-oriented health policies to address disparities and enhance overall health outcomes, particularly in rapidly developing regions like China.

Despite global efforts to improve health, significant health inequalities persist across various geographic scales, from countries to neighborhoods.[12,13] A key strength of our study is its detailed examination of geographic CVH disparities at the township level in Ruyang County, China. Ruyang, with an area of 1,332 km^2—comparable to London's 1,572 km^2—displays considerable geographic and economic variation. Chengguan, the county's urban center, has the highest population density, while southern Ruyang is predominantly mountainous with an economy based on agriculture and forestry. In contrast, the northern plain areas are centered on manufacturing and food processing. This significant geographic and socioeconomic diversity underscores the need for region-specific health promotion strategies. Although this study was conducted in Ruyang County, this region serves as a representative microcosm of developing counties in China and other low-to-middle-income settings.

China's diverse socioeconomic and topographic landscape has long been associated with geographic variations in CVH. Traditionally, populations within the same county were viewed as economically and culturally homogeneous, often forming the basis for health policy design and implementation. In contrast to previous macro-level studies, our research reveals significant CVH disparities among townships within a single county. From a policy perspective, our findings suggest that a 'one-size-fits-all' approach is insufficient. The observed township-level and

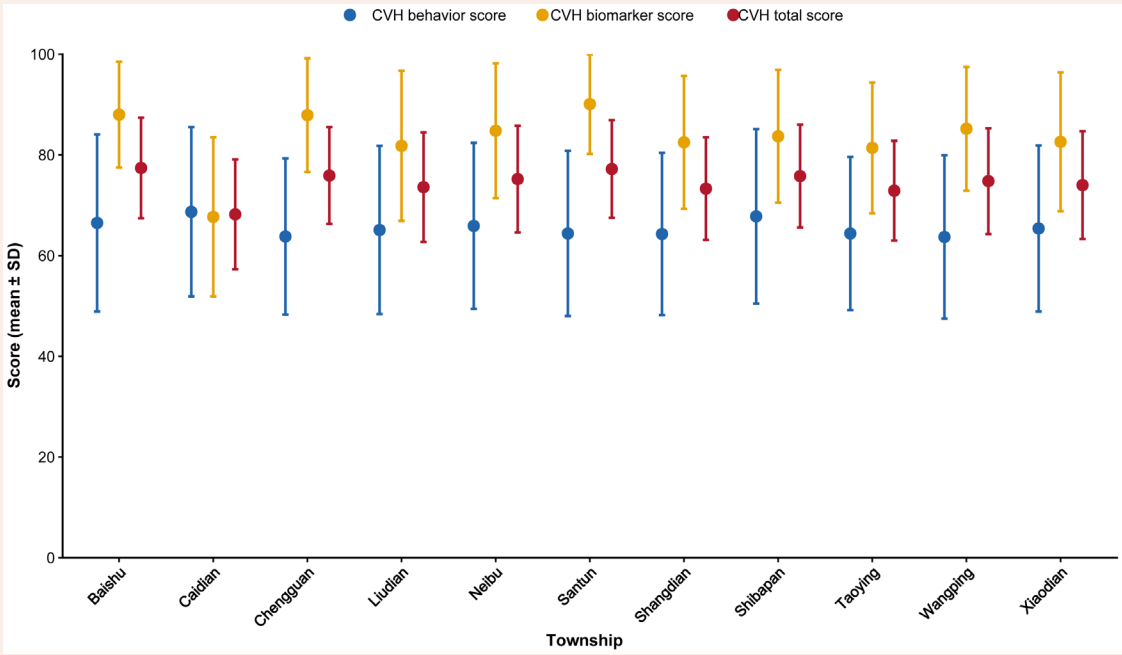


Figure 2. Overall, behavior, and biomarker CVH metrics by 11 townships in Ruyang. CVH = cardiovascular health.

sex-based disparities in CVH reflect systemic challenges in primary healthcare delivery and health literacy, serving as a valuable reference for similar socioeconomic contexts. Our finding that CVH status varies significantly at the township level suggests that public health resources should be allocated based on micro-level geographic risk. Given the inferior biomarker profiles observed in women, future initiatives should prioritize health screening and promote access to care for rural elderly females.

Our findings highlight the complicated impact of socioeconomic status on cardiovascular behavior and biomarker health profiles. We found that higher

Table 2

Age-sex-standardized ideal rates of individual components of LE8 metrics by 11 townships in Ruyang.

Township	Diet	Physical activity	Nicotine exposure	Sleep health	Body mass index	Blood lipid	Blood glucose	Blood pressure
Baishu	0.02 (0.01,0.03)	0.54 (0.46,0.61)	0.74 (0.65,0.83)	0.47 (0.40,0.54)	0.74 (0.65,0.83)	0.86 (0.77,0.96)	0.65 (0.56,0.73)	0.52 (0.45,0.59)
Caidian	0.04 (0.03,0.05)	0.50 (0.47,0.54)	0.84 (0.80,0.88)	0.56 (0.53,0.60)	0.69 (0.65,0.72)	0.14 (0.12,0.15)	0.70 (0.66,0.74)	0.37 (0.34,0.39)
Chengguan	0.04 (0.03,0.05)	0.20 (0.17,0.22)	0.86 (0.81,0.91)	0.53 (0.49,0.58)	0.76 (0.71,0.81)	0.81 (0.76,0.85)	0.83 (0.78,0.88)	0.52 (0.48,0.56)
Liudian	0.05 (0.03,0.07)	0.34 (0.28,0.39)	0.83 (0.75,0.91)	0.48 (0.42,0.55)	0.68 (0.60,0.75)	0.58 (0.51,0.65)	0.82 (0.73,0.91)	0.43 (0.37,0.49)
Neibu	0.09 (0.07,0.10)	0.46 (0.42,0.50)	0.81 (0.75,0.86)	0.55 (0.51,0.60)	0.63 (0.58,0.68)	0.84 (0.78,0.89)	0.84 (0.78,0.90)	0.47 (0.43,0.51)
Santun	0.03 (0.02,0.05)	0.38 (0.33,0.42)	0.78 (0.68,0.88)	0.46 (0.41,0.51)	0.80 (0.70,0.89)	0.90 (0.80,1.00)	0.86 (0.76,0.96)	0.49 (0.40,0.58)
Shangdian	0.03 (0.02,0.04)	0.36 (0.31,0.41)	0.74 (0.67,0.81)	0.5 (0.46,0.54)	0.68 (0.62,0.74)	0.62 (0.56,0.67)	0.79 (0.73,0.86)	0.39 (0.34,0.44)
Shibapan	0.14 (0.10,0.18)	0.40 (0.33,0.47)	0.84 (0.73,0.94)	0.53 (0.45,0.62)	0.71 (0.61,0.81)	0.65 (0.56,0.74)	0.84 (0.73,0.96)	0.49 (0.41,0.57)
Taoying	0.03 (0.02,0.04)	0.26 (0.22,0.30)	0.82 (0.72,0.93)	0.65 (0.55,0.75)	0.60 (0.54,0.66)	0.51 (0.46,0.57)	0.85 (0.77,0.93)	0.39 (0.30,0.47)
Wangping	0.01 (0.00,0.03)	0.26 (0.19,0.33)	0.79 (0.66,0.92)	0.54 (0.43,0.64)	0.68 (0.57,0.79)	0.74 (0.62,0.86)	0.76 (0.64,0.88)	0.34 (0.26,0.42)
Xiaodian	0.07 (0.05,0.08)	0.36 (0.33,0.39)	0.84 (0.80,0.89)	0.54 (0.51,0.58)	0.64 (0.6,0.68)	0.64 (0.60,0.68)	0.91 (0.86,0.96)	0.42 (0.39,0.45)

Data are presented as rates (95% CI).
CI = confidence interval.

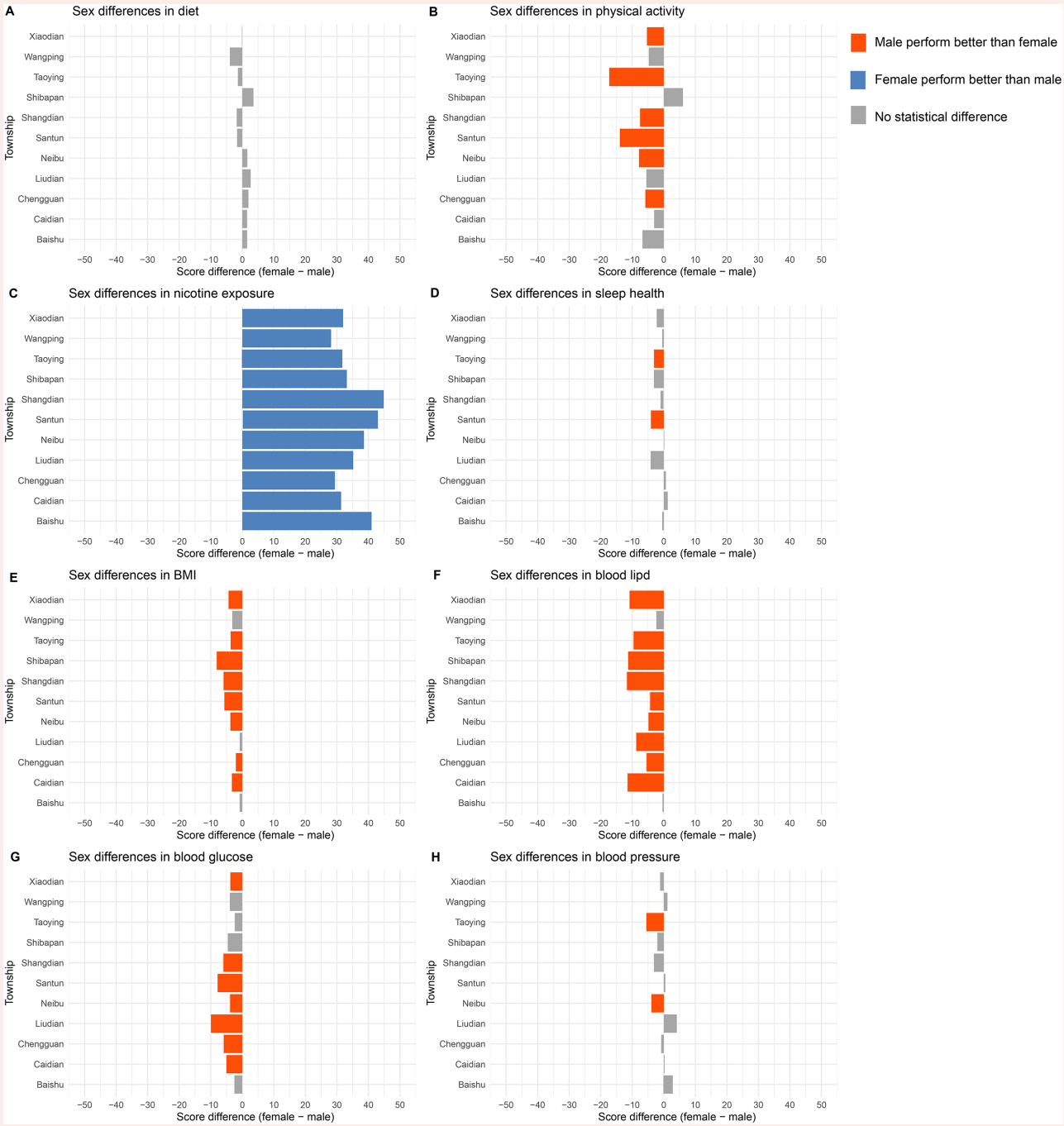


Figure 3. Comparison of CVH metrics between females and males (reference) by 11 townships in Ruyang. Sex differences in diet (A), physical activity (B), nicotine exposure (C), sleep health (D), BMI (E), blood lipid (F), blood glucose (G), blood pressure (H) metrics by 11 townships in Ruyang. Red bars indicate that males perform better than females and blue bars indicate that females perform better than males. Grey bars indicate no statistical difference between females and males. An unpaired *t* test was used to test the difference between females and males. CVH = cardiovascular health.

socioeconomic status (e.g., higher education level) is associated with improved health behaviors but not necessarily with more favorable cardiometabolic biomarkers. This pattern reflects the multifaceted influence of socioeconomic status on CVH, including limited access to healthy foods, healthcare infrastructure, and cumulative life-course exposures—factors that may limit the translation of behavioral improvements into better cardiometabolic biomarkers.[14] A higher educational degree does not inherently equate to high health literacy. Furthermore, although it may foster favorable health intentions and behaviors, it does not necessarily translate into the structural resources required to improve CVH status. Zhang et al. reported that unhealthy lifestyles mediated only a small proportion of the socioeconomic inequity in mortality and incident CVD among both US and UK

Table 3

Relationships between socioeconomic factors and CVH.

	Beta	SE	*p* Value
CVH behavior score			
Age	–0.37	0.02	< 0.001
Female (vs. male)	7.47	0.35	< 0.001
Middle school and above (vs. primary school and below)	2.34	0.46	< 0.001
Nonmarried (vs. married)	–2.37	0.43	< 0.001
Nonagriculture (vs. agriculture)	–5.09	0.43	< 0.001
CVH biomarker score			
Age	0.18	0.02	< 0.001
Female (vs. male)	–5.50	0.35	< 0.001
Middle school and above (vs. primary school and below)	–2.12	0.46	< 0.001
Nonmarried (vs. married)	0.72	0.43	0.095
Nonagriculture (vs. agriculture)	–0.07	0.43	0.873

Multivariable linear regression models incorporating age, sex, education, marital status, and agriculture.
CVH = cardiovascular health.

adults.[15] Therefore, promoting healthy lifestyles alone may be insufficient to substantially reduce socioeconomic inequities in CVH, and additional measures addressing the social determinants of CVH are warranted.

Identifying sex differences in CVH is essential for developing sex-specific health policies. In our study, women scored higher in behavioral metrics, particularly in tobacco use, aligning with previous reports. However, women exhibited a higher prevalence of several CVH risk factors, including hyperlipidemia, overweight, and elevated glucose levels. This finding contrasts with previous national-level data from China that consistently demonstrated that women generally exhibit lower prevalence and higher awareness, treatment, and control rates for hypertension and diabetes than men.[16–18] The China Chronic Disease and Risk Factors Surveillance program has also reported lower BMI and prevalence of obesity in women.[19] However, our study demographic profile differs significantly from national representative samples. While national surveys typically focus on middle-aged populations with higher urbanization and education levels, our study population consists of older adults residing in a rural county with a low education level and engaging in agricultural production. It should be noted that 69.5% of women are illiterate, compared with 35% of men. Low socioeconomic status, limited health literacy, and restricted access to high-quality healthcare are well-recognized correlates of poor CVH, which were highly prevalent among women in our study. The Berlin female risk evaluation study demonstrated that older age and low health literacy correlate with an underestimation of cardiovascular risk in women.[20] On the other hand, poor control of cholesterol levels has also been observed among women in national studies. The China PEACE Million Persons Project showed that women had a higher prevalence of elevated total cholesterol, low-density lipoprotein cholesterol, and triglycerides (TG) compared with men, aligning with our data.[21] This trend is mirrored internationally; a recent large-scale Swedish study revealed that inferior low-density lipoprotein cholesterol control remains a primary sex-related difference in modifiable CVD risk, likely reflecting a clinical underestimation of lipid management needs in women.[8] Therefore, targeted health policies are needed to address these disparities, with a focus on rural women to ensure more equitable health outcomes.

This study has several limitations. First, being a cross-sectional survey, it does not allow for causal inferences regarding the impact of socioeconomic variables on CVH. Second, the absence of longitudinal data limits our ability to assess temporal trends in CVH risk factors. Nonetheless, we have performed an age-stratified analysis to partially reflect generational and aging-related differences in CVH patterns, warranting validation through longitudinal cohort studies. Third, we adapted the dietary approaches to stop hypertension diet components because self-reported sodium intake and the distinction between fruits and vegetables were inaccurate in the rural elderly population. We also adapted the record the frequency (days per week) of physical activity rather than duration (minutes) to minimize recall bias. Despite being principally consistent with the AHA LE8 framework, the modified LE8 scoring system may not fully capture CVH status.[11,22] Fourth, the information on drugs for hypertension, diabetes, and dyslipidemia was not collected in the health checkup program. However, given the low control rates in the rural elderly population, the CVH biomarker status of most participants remained physically detectable regardless of medication use, reducing the likelihood of "medication masking" bias. Fifth, the lack of data on individual (e.g., income, access to healthcare) and township-level (e.g., GDP per capita, primary industry proportion, average income) socioeconomic variables limits the investigation into the socioeconomic impact on CVH. While the present findings provide a critical descriptive mapping of CVH, future research is essential to investigate the specific socioeconomic mechanisms. Sixth, this study only included the elderly population aged ≥ 65 years, who bear the highest burden of cardiovascular risk and are the primary targets of China's national health screening initiative. Our findings are not generalizable to a broader age range.

Lastly, 3 townships (Jincun, Fudian, Daan) were excluded due to low participation rates and incomplete data coverage during the government-led health screening. The exclusion of 3 townships from Ruyang could potentially affect the representativeness of the study sample. Despite the government-organized health checkup program's broad coverage, convenience sampling at both the village and individual levels may introduce selection bias. Consequently, the study sample may not fully represent the general population and limit the generalizability of our findings.

5. Conclusion

The emergence of geographic and sex health inequalities in township scale during socioeconomic transition underscores the need for more targeted health promotion interventions that address both regional and sex-specific factors.

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Ethical statement

This study utilized publicly available data from the chronic disease screening program for analysis. Written informed consent was obtained during the public screening program. Researchers did not have access to any identifiable personal information. The ethics committee of the Ruyang County People's Hospital waived the ethical review of this study as a derivative data analysis of the completed public screening program. This study was conducted in accordance with the Declaration of Helsinki.

Conflicts of interest

The authors have no conflicts of interest to disclose.

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Data availability statement

All data and codes used in the analysis and projections are available upon request to the corresponding author.

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AI statement

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