

Postprint of a Prospective Cohort Study on the Impact of Socioeconomic Status and Healthy Lifestyle on Cardiovascular Disease

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Abstract

Background Cardiovascular disease (CVD) is a global health problem, and it is currently unclear whether socioeconomic status (SES) and healthy lifestyle (HL) have an impact on CVD incidence. Objective To understand the relationship between SES, HL and CVD, and to provide a basis for CVD prevention and control in the population. Methods This study employed a multistage cluster random sampling method to conduct a baseline survey in 2010 among 9,280 permanent residents aged 18 years and older from 12 counties/districts in Guizhou Province. All individuals in this cohort were followed up from 2016 to 2020. Face-to-face interviews were conducted by uniformly trained and qualified personnel, covering basic demographic information, lifestyle factors (smoking, alcohol consumption, fruit and vegetable intake, etc.), and previous disease history. A total of 4,148 individuals were ultimately included in the analysis and divided into a CVD group (123 individuals) and a non-CVD group (4,025 individuals) based on whether they developed the disease. COX proportional hazards regression models were used to analyze the effects of SES and HL on CVD incidence, while accelerated failure time models were employed to analyze the impact of different SES and HL on the time to CVD onset. After excluding individuals with baseline CVD, those lost to follow-up, and those with missing information, the final effective sample size included in the analysis was 4,148 individuals, with 123 CVD cases identified, yielding an incidence density of 4.13 per 1,000 person-years. COX proportional hazards regression model analysis revealed that, compared with individuals in the low SES group, those in the high SES group had a 40.60% lower risk of CVD incidence (HR=0.594, 95%CI=0.402-0.878). Compared with individuals with \$ \$6 types of HL, those with 8 types and \$ \$9 types of HL showed a 44.40% (HR=0.556, 95%CI=0.320-0.968) and 49.20% (HR=0.508, 95%CI=0.284-0.912) reduction in CVD risk, respectively. Compared with individuals with low SES and \$ \$6 types of HL, those with

low SES and 7, 8, or 9 types of HL showed no statistically significant difference in CVD risk ($P>0.05$); however, individuals with high SES and 8 or 9 types of HL experienced a 61.80% ($HR=0.382$, $95\%CI=0.163-0.894$) and 70.20% ($HR=0.298$, $95\%CI=0.119-0.748$) reduction in CVD risk, respectively, demonstrating a decreasing trend (P for trend <0.001). Accelerated failure time model results indicated that, compared with individuals with low SES and 6 types of HL, those with high SES and 8 or 9 types of HL had their CVD onset delayed by 1.148 years ($95\%CI=0.049-2.247$) and 1.407 years ($95\%CI=0.227-2.588$), respectively. Conclusion Different SES and HL are negatively correlated with CVD incidence; among individuals with high SES, the time to CVD onset prolongs with increasing number of HL types. Populations with low SES represent a key target group for CVD prevention and control in Guizhou Province, and measures should be taken to improve their health literacy while conducting targeted health education and health promotion activities for CVD.

Full Text

A Prospective Cohort Study on the Impact of Socioeconomic Status and Healthy Lifestyle on Cardiovascular Disease

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Abstract

Background Cardiovascular disease (CVD) represents a global health challenge, yet the specific impacts of socioeconomic status (SES) and healthy lifestyle (HL) on CVD incidence remain unclear. **Objective** This study examines the relationship between SES, HL, and CVD to inform evidence-based prevention and control strategies. **Methods** Using multi-stage cluster random sampling, we recruited 9,280 permanent residents aged 18 years and older from 12 counties and districts in Guizhou Province for baseline assessment in 2010. Follow-up was conducted from 2016 to 2020 through face-to-face interviews administered by uniformly trained and certified personnel, covering demographic characteristics, lifestyle factors (smoking, alcohol consumption, fruit and vegetable intake), and medical history. After excluding participants

with baseline CVD, those lost to follow-up, and those with missing data, 4,148 individuals were included in the final analysis and divided into CVD group (n=123) and non-CVD group (n=4,025). Cox proportional hazards regression models were employed to analyze the effects of SES and HL on CVD incidence, while accelerated failure time models assessed their impact on time to CVD onset. **Results** The final analytic sample comprised 4,148 participants with 123 incident CVD cases, yielding an incidence density of 4.13 per 1,000 person-years. Multivariate Cox regression revealed that, compared with low SES individuals, those with high SES had a 40.60% reduced risk of CVD (HR=0.594, 95%CI=0.402-0.878). Compared with individuals practicing \$6 healthy lifestyle behaviors, those with 8 and \$9 healthy behaviors showed 44.40% (HR=0.556, 95%CI=0.320-0.968) and 49.20% (HR=0.508, 95%CI=0.284-0.912) reductions in CVD risk, respectively. In joint analyses, no statistically significant associations were observed between HL categories (7, 8, or \$9 behaviors) and CVD risk among low SES participants (P>0.05). However, among high SES individuals, those with 8 and \$9 healthy lifestyle behaviors experienced 61.80% (HR=0.382, 95%CI=0.163-0.894) and 70.20% (HR=0.298, 95%CI=0.119-0.748) reductions in CVD risk, respectively, demonstrating a significant dose-response trend (P-trend<0.001). Accelerated failure time models showed that, compared with low SES individuals practicing \$6 healthy behaviors, high SES participants with 8 and \$9 healthy behaviors delayed CVD onset by 1.148 years (95%CI=0.049-2.247) and 1.407 years (95%CI=0.227-2.588), respectively. **Conclusion** Both higher SES and greater numbers of healthy lifestyle behaviors are independently and jointly associated with reduced CVD incidence and delayed onset, particularly among high SES populations. Low SES populations represent a priority target for CVD prevention and control in Guizhou Province, warranting targeted health literacy interventions and tailored health education and promotion initiatives.

Keywords Cardiovascular diseases; Socioeconomic status; Healthy lifestyle; Cox regression analysis; Cohort study

1. Subjects and Methods

1.1 Study Population

This study utilized the Guizhou Natural Population Cohort. In 2010, we employed multi-stage cluster random sampling to select 9,280 permanent residents aged 18 years and older from 12 counties and districts across Guizhou Province for baseline survey. Follow-up was conducted from 2016 to 2020, successfully tracking 8,163 participants with 1,117 lost to follow-up (follow-up rate: 87.96%). Inclusion criteria comprised: (1) absence of CVD at baseline; (2) age \$18 years; and (3) complete physical examination data (including SES scores, lifestyle factors, health status, anthropometric measurements, and laboratory tests). Exclusion criteria included: (1) missing survey information or loss to follow-up;

(2) refusal to provide informed consent or participate; and (3) incomplete data. After excluding 1,117 lost to follow-up, 40 baseline CVD cases, 8 with unclear disease status, and 3,967 who reported “unknown income,” “refused to answer,” or provided other invalid responses regarding annual household income, 4,148 participants were included in the final analysis. The study protocol was approved by the Ethics Committee of Guizhou Provincial Center for Disease Control and Prevention (Approval No. S2017-02), and all participants provided written informed consent.

1.2 Data Collection

1.2.1 Questionnaire Survey We administered the China Chronic Disease Surveillance Questionnaire developed by the Chinese Center for Disease Control and Prevention through one-on-one face-to-face interviews conducted by uniformly trained and certified interviewers. The questionnaire collected information on demographic characteristics (sex, age, ethnicity, occupation), annual household income, education level, lifestyle factors (smoking, alcohol consumption, fruit and vegetable intake), and medical history.

1.2.2 Physical Examination Blood pressure was measured using an Omron HBP-1300 electronic sphygmomanometer (Omron Dalian Co., Ltd.). Participants rested for five minutes prior to measurement, with two readings taken 1–2 minutes apart and averaged. If systolic or diastolic pressure differed by >5 mmHg (1 mmHg=0.133 kPa), a third measurement was taken and the average of three readings was used. Height and weight were measured using a TZG-210 stadiometer customized by the National CDC and Sports Commission. Participants wore light clothing without shoes, stood straight with arms at their sides, eyes forward, and remained stationary. Two measurements were taken and averaged, recorded to 0.1 cm and 0.1 kg precision.

1.2.3 Laboratory Testing After an overnight fast of at least 8 hours, fasting venous blood samples were collected. Fasting plasma glucose (FPG) was measured using the hexokinase method in quality-controlled laboratories. Remaining samples were centrifuged, and serum was separated and stored at -20°C before being transported to Guizhou Provincial CDC for measurement of total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) using an Olympus AU400 automatic biochemical analyzer (Beckman Coulter, USA).

1.2.4 SES Scoring Following established SES measurement methodology [?], we used annual per capita household income, occupation type, and individual education level as SES indicators. Each indicator was scored from 1 to 4 based on ordinal ranking (Table 1). Annual per capita income was categorized into quartiles. Each participant’s total SES score represented the sum of scores across the three domains, with participants dichotomized into low SES (≤ 7 points) and high SES (>7 points) groups based on the median composite score.

1.2.5 HL Scoring Based on established CVD risk factors, we assessed 12

healthy lifestyle behaviors: never drinking alcohol, never smoking, 7-9 hours of sleep daily, fruit and vegetable intake ≥ 400 g/day, cooking oil intake ≤ 25 g/day, salt intake < 6 g/day, waist-to-height ratio < 0.5 , ≤ 150 minutes of moderate-intensity exercise weekly, no fried food consumption, total sedentary time < 4 hours/day, grain and tuber intake ≤ 200 g/day, and good mental health. Each behavior was coded as 1 (present) or 0 (absent), yielding a total score ranging from 0 to 12. Categories were collapsed into four groups: ≤ 6 , 7, 8, and ≥ 9 healthy lifestyle behaviors.

1.3 Diagnostic Criteria and Definitions

(1) **CVD Diagnosis** [?] Participants were classified as having CVD if they self-reported a physician diagnosis or if death records indicated myocardial infarction, cerebral hemorrhage, or cerebral infarction as the underlying cause. Participants were categorized into CVD and non-CVD groups accordingly.

(2) **Hypertension** [?] Defined as self-reported physician diagnosis or antihypertensive treatment, or measured systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg.

(3) **Diabetes** [?] Defined as self-reported physician diagnosis or glucose-lowering treatment, or FPG ≥ 7.0 mmol/L, or 2-hour oral glucose tolerance test ≥ 11.1 mmol/L, or HbA1c $\geq 6.5\%$.

(4) **Dyslipidemia** [?] Defined as self-reported physician diagnosis or lipid-lowering medication use, or TC ≥ 6.22 mmol/L, or TG ≥ 2.26 mmol/L, or HDL-C < 1.04 mmol/L, or LDL-C ≥ 4.14 mmol/L.

(5) **Body Mass Index (BMI)** Calculated as weight (kg) divided by height squared (m^2).

(6) **Waist-to-Height Ratio (WHtR)** Calculated as waist circumference (cm) divided by height (cm).

(7) **Mental Health Status** [?] Assessed using the Patient Health Questionnaire-9 (PHQ-9). Scores ≤ 4 indicated good mental health, while scores > 4 indicated poor mental health.

1.4 Statistical Analysis

Data analysis was performed using SPSS 26.0, with forest plots generated in GraphPad Prism 8.0. Normally distributed continuous variables were expressed as mean \pm standard deviation and compared using independent samples t-tests. Categorical variables were presented as frequencies and percentages, compared using chi-square tests. Cox proportional hazards regression models were used to examine associations between SES, HL, and CVD incidence, with SES scores, HL scores, and CVD status as independent and dependent variables, respectively. Proportional hazards assumptions were tested using R 4.2.3. Accelerated failure time models quantified the impact of SES and HL on time to CVD

onset. Statistical significance was set at $P < 0.05$.

2. Results

2.1 Baseline Characteristics

The final analytic sample included 4,148 participants (1,998 men [48.20%] and 2,150 women [51.80%]) with a median follow-up of 6.50 person-years. During follow-up, 123 incident CVD cases were identified. Participants aged ≥ 44 years accounted for 53.60% (2,223/4,148) of the cohort. Manual laborers comprised 58.90% (2,442/4,148), 30.10% (1,249/4,148) had annual per capita household income $\leq 10,000$ yuan, 49.30% (2,044/4,148) were classified as low SES, and 24.00% (994/4,148) practiced ≥ 9 healthy lifestyle behaviors. Normal BMI was most common (2,518 participants [60.70%]). The CVD and non-CVD groups differed significantly in age distribution, ethnicity, marital status, education level, SES category, sleep duration (7-9 hours/day), salt intake (< 6 g/day), waist-to-height ratio (< 0.5), mental health status, hypertension history, and HL category ($P < 0.05$) (Table 2).

2.2 Association Analyses

2.2.1 SES and CVD Incidence Using CVD status as the dependent variable (1=incident CVD, 0=no CVD) and SES category as the independent variable (1=low SES, 2=high SES), multivariate Cox regression adjusting for confounders showed that high SES was associated with a 40.60% reduction in CVD risk compared with low SES (HR=0.594, 95%CI=0.402-0.878, P-trend=0.009) (Table 3).

2.2.2 HL and CVD Incidence With CVD status as the outcome and HL category as the predictor (1= ≤ 6 behaviors, 2 = 7 behaviors, 3 = 8 behaviors, 4 = ≥ 9 behaviors), adjusted analyses revealed that individuals with 8 and ≥ 9 healthy lifestyle behaviors had 44.44% (HR=0.556, 95%CI=0.320-0.968) and 49.20% (HR=0.508, 95%CI=0.284-0.912) reductions in CVD risk, respectively, compared with those practicing ≤ 6 behaviors (P-trend=0.004) (Table 4).

2.2.3 Joint Effects of SES and HL on CVD Incidence In joint analyses using CVD status as the outcome and combined SES-HL categories as predictors (1=low SES/ ≤ 6 behaviors through 8 = high SES/ ≥ 9 behaviors), no significant associations were observed between HL categories and CVD risk among low SES participants ($P > 0.05$). However, among high SES individuals, those with 8 and ≥ 9 healthy lifestyle behaviors experienced 61.80% (HR=0.382, 95%CI=0.163-0.894) and 70.20% (HR=0.298, 95%CI=0.119-0.748) reductions in CVD risk, respectively, relative to low SES participants with ≤ 6 healthy behaviors, demonstrating a significant dose-response trend (P-trend < 0.001) (Table 5).

2.2.4 Accelerated Failure Time Models To quantify the impact on time to CVD onset, accelerated failure time models showed that, compared with

low SES individuals practicing 8 healthy behaviors, high SES participants with 8 and 9 healthy lifestyle behaviors delayed CVD onset by 1.148 years (95%CI=0.049-2.247) and 1.407 years (95%CI=0.227-2.588), respectively (Figure 2 [Figure 2: see original paper]).

2.2.5 Sensitivity Analyses To ensure robustness, we conducted sensitivity analyses: (1) excluding participants with baseline diabetes, and (2) excluding CVD cases with less than 6 years of follow-up. Results remained consistent with primary analyses after multivariate adjustment (Figure 3 [Figure 3: see original paper]).

3. Discussion

As a leading global cause of mortality [?], CVD claims approximately 17.9 million lives annually [?], imposing substantial economic burden. Social determinants of health influence CVD risk through economic, environmental, and psychosocial pathways [?, ?]. Numerous studies have demonstrated that SES and HL affect disease outcomes [?, ?], with low SES associated with higher CVD risk [?] and healthy lifestyles reducing CVD incidence. However, few studies have examined their joint effects. This prospective cohort study addresses this gap by investigating how SES and HL independently and jointly influence CVD incidence and onset time in a Guizhou adult population.

Our findings demonstrate that high SES is associated with 40.60% lower CVD risk compared with low SES, consistent with Wang et al.'s research [?] but contrasting with studies reporting higher CVD risk in high SES populations [?], possibly due to excessive consumption of high-fat, high-sugar diets among affluent groups. SES influences access to resources (knowledge, wealth, power, healthcare services) [?]. Higher-income individuals face lower financial barriers, have greater healthcare access, and exhibit better health literacy and adherence to healthy behaviors. Manual laborers experience lower job control [?], and shift workers face circadian disruption leading to metabolic disturbances, hypertension, atherosclerosis, and obesity.

Healthy lifestyle behaviors are well-established protective factors against CVD [?], with evidence showing that accumulating more healthy behaviors progressively reduces risk [?]. Tsai et al. [?] demonstrated inverse associations between HL scores and CVD incidence in a national cohort, with risk reductions of 0.77, 0.53, and 0.43 for scores of 2, 3, and 4-5, respectively, compared with scores of 0-1—findings that align with our observation of 44.40% and 49.20% risk reductions for individuals with 8 and 9 healthy behaviors versus 6.

Notably, we found that increasing healthy lifestyle behaviors did not significantly reduce CVD risk among low SES participants, whereas high SES individuals showed progressively lower risk and delayed onset with more healthy behaviors. Compared with low SES participants practicing 6 healthy behaviors, high

SES individuals with 8 and \$ \$9 behaviors delayed CVD onset by 1.148 and 1.407 years, respectively. These findings differ from Zhang et al. [?], who reported HL benefits across all SES levels. This discrepancy may reflect regional economic disparities and health inequities [?]. Low SES individuals have limited economic resources, reduced healthcare access [?], lower health literacy [?], and greater psychosocial stress [?, ?], potentially diminishing the protective effects of lifestyle modifications. The complex pathophysiology of CVD and multifactorial risk profile suggests that for low SES populations, structural barriers and psychosocial factors may outweigh lifestyle influences, highlighting the need for targeted interventions.

Our study has several limitations. SES measurement lacks standardized international criteria, and self-reported SES and HL data may be subject to recall bias. Unmeasured confounders may persist despite multivariate adjustment. However, as a prospective cohort study with robust sensitivity analyses, our findings provide strong epidemiological evidence for causal inference and underscore the importance of addressing both SES disparities and lifestyle factors in CVD prevention, particularly for vulnerable low SES populations in Guizhou Province.

Author Contributions: AN Qinyu conceptualized and designed the study, supervised implementation, and drafted the manuscript. WANG Yiying, ZHANG Xiaodan, and ZHANG Tianlin collected and processed data, performed statistical analyses, and prepared figures and tables. ZHAN Qingqing and ZHANG Fuyan revised the manuscript. LIU Tao and WU Yanli oversaw quality control, reviewed the manuscript, and assume overall responsibility for the work.

Conflicts of Interest: None declared.

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Tables and Figures

Table 1 Criteria for Assigning Measurement Indicators of SES

Table 2 Baseline Characteristics of Participants (N=4,148)

Table 3 COX Regression Analysis of CVD Onset by SES

Table 4 COX Regression Analysis of Healthy Lifestyle on CVD Onset

Table 5 COX Regression Analysis of SES and Healthy Lifestyle on CVD Onset

Figure 1 [Figure 1: see original paper] A Flow Chart of This Study

Figure 2 [Figure 2: see original paper] Analysis of the Delay Time of CVD Onset

by SES and Healthy Lifestyle

Figure 3 [Figure 3: see original paper] A Sensitivity Analysis

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