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Investigating the role of modifiable risk factors in cardiovascular disease outcomes: A statistical analysis using BRFSS data

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Abstract

Background: Cardiovascular disease (CVD) is a major global health challenge, influenced by various demographic, socioeconomic, and lifestyle factors. Understanding the role of modifiable risk factors is crucial for developing targeted public health interventions. This study investigates the predictors of CVD using data from the Behavioral Risk Factor Surveillance System (BRFSS), with a focus on identifying high-risk populations and key modifiable contributors.

Methods: A generalized linear model (GLM) with a logit link was applied to BRFSS data, comprising 169,982 observations. Key predictors, including age, sex, race, smoking, alcohol consumption, physical activity, and residential setting, were assessed for their associations with CVD. Odds ratios (ORs) and confidence intervals (CIs) were calculated to evaluate the strength and significance of these predictors.

Results: Age was the strongest predictor of CVD, with individuals aged 45 and above having over 10 times higher odds (OR = 10.09, $p < 0.001$) compared to those aged 18–44. Men exhibited a higher prevalence of CVD (6.37%) than women (3.83%), and white individuals showed higher odds of CVD compared to minority groups. Modifiable lifestyle factors were significant: smoking and alcohol use increased CVD risk, while regular exercise demonstrated a protective effect ($p < 0.001$). Additionally, rural residents had a slightly higher prevalence of CVD than urban residents, underscoring healthcare disparities across residential settings.

Conclusion: This study highlights the critical role of age, sex, race, and lifestyle behaviors in CVD outcomes. Tailored public health strategies targeting older adults, men, and rural populations are essential. Interventions promoting smoking cessation, reduced alcohol use, and increased physical activity can substantially reduce CVD risk. These findings reinforce the importance of addressing healthcare disparities and advancing evidence-based strategies to mitigate the burden of cardiovascular disease.

Keywords: Cardiovascular Disease (CVD); Generalized Linear Model (GLM); Modifiable Risk Factors; BRFSS; Public Health

1. Introduction

Cardiovascular disease (CVD) is the leading cause of death globally, claiming nearly 17.9 million lives each year [1]. CVD encompasses a range of conditions affecting the heart and blood vessels, including coronary artery disease and stroke. Its prevalence is increasing due to factors like lifestyle changes, urbanization, and an aging population [2]. CVD includes

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various disorders of the cardiac muscle and vascular system, impacting the heart, brain, and other vital organs [3]. Several factors contribute to the development and progression of CVD, which can generally be categorized as modifiable and non-modifiable. Modifiable risk factors include behaviors and conditions that can be managed or altered, such as smoking, obesity, poor diet, hypertension, and physical inactivity. These factors significantly impact CVD risk and are central to preventive health efforts aimed at reducing disease incidence and severity [4, 5]. Non-modifiable risk factors, such as age, sex, and genetic predispositions, are also crucial in determining CVD risk, although they cannot be directly addressed through behavioral changes [6]. Among non-modifiable factors, age stands out as one of the strongest predictors of cardiovascular events [7], underscoring its relevance in CVD research and prevention strategies.

This study aims to examine the association between modifiable risk factors and CVD outcomes, using data from the Behavioral Risk Factor Surveillance System (BRFSS) from 2020. By applying multiple logistic regression model, the study assesses the impact of factors such as body mass index (BMI), smoking, diabetes, blood pressure, and cholesterol levels, along with lifestyle factors. By identifying key risk factors, this research seeks to inform public health initiatives focused on reducing CVD prevalence through targeted lifestyle modifications and health interventions.

2. Literature Review

The rising prevalence of cardiovascular disease has prompted extensive research into its risk factors. Research into these factors provides a foundation for public health initiatives aimed at preventing CVD and reducing its burden across diverse populations. Numerous studies have identified modifiable lifestyle behaviors such as smoking, poor diet, lack of physical activity, and excessive alcohol consumption as significant contributors to CVD development [1] nearly 80% of global CVD deaths occur in low- and middle-income countries (LMIC) where CVD and risk factor burden are on the rise as a result of an ongoing epidemiological transition. Research by Yusuf et al. [4] suggests that nearly 80% of premature CVD-related deaths are preventable by addressing these risk factors.

One of the landmark studies in this area, the INTERHEART study, conducted by Yusuf et al. [8], identified key modifiable risk factors associated with myocardial infarction through a case-control design across 52 countries. The study highlights that lifestyle factors, including smoking, physical inactivity, and obesity, significantly contribute to myocardial infarction risk, offering robust evidence for global prevention strategies targeting these factors. Similarly, findings by Mozaffarian et al. [9] from the American Heart Association reinforce the importance of modifiable factors, synthesizing U.S. data on CVD prevalence and risk factors to underscore lifestyle interventions' effectiveness in high-risk populations.

Ezzati and Riboli [10] provide further insights into behavioral and dietary risk factors for noncommunicable diseases (NCDs), including CVD, by analyzing how poor diet and sedentary behavior are intricately linked to increased disease incidence. This review calls for integrated public health policies that promote healthy dietary habits and physical activity as key strategies for reducing CVD prevalence. In line with these findings, the WHO's 2023 Global Status Report on Noncommunicable Diseases recommends global interventions targeting modifiable behaviors like smoking and poor diet to combat the rising tide of CVD and other NCDs.

In the review studies of Mohammadnezhad et al. [11], modifiable and non-modifiable risk factors both play a key role in the increasing prevalence of non-communicable diseases (NCDs), particularly cardiovascular disease (CVD), in Pacific Island nations. A total of 45 studies met the inclusion criteria for this review. The findings revealed that age was the most frequently cited non-modifiable risk factor, while diabetes, elevated blood lipid levels, and high blood pressure were the most reported modifiable risk factors for CVD. Only three interventional studies were identified, all of which demonstrated a significant reduction in CVD risk factors when compared to control groups. Global estimates of the effect of common modifiable risk factors on cardio- vascular disease and mortality are largely based on data from separate studies, using different methodologies [4].

According to a study by Arafa et al. [12], hypertension, diabetes, dyslipidemia, cigarette smoking, physical inactivity, obesity, and poor-quality diet are major modifiable risk factors for cardiovascular disease (CVD). It was further identified that physical inactivity exhibits the highest prevalence among the risk factors, followed by hypertension and obesity. Implementation of primordial prevention strategies focused on the above-mentioned risk factors should be the priority of the health policymakers to tackle the growing burden of CVD.

In the study by Update [13], coronary heart disease (CHD) and stroke are estimated to cause more than 470,000 deaths annually. To inform primary prevention policies, it was estimated that sex- and age-specific burden of CHD and stroke were attributable to five major and modifiable vascular risk factors: cigarette smoking, hypertension, diabetes, elevated total cholesterol, and excess body weight.

A significant body of literature highlights the role of hypertension in CVD outcomes. According to Forouzanfar et al. [14], high blood pressure is the leading risk factor for heart disease and stroke globally. Globally, over 1 billion people have hypertension, with the number expected to reach 1.5 billion by 2025 due to aging populations and more sedentary lifestyles. Elevated blood pressure (BP) is the leading cause of premature death worldwide, responsible for nearly 10 million deaths in 2015, including 4.9 million from ischemic heart disease and 3.5 million from stroke. Hypertension also significantly increases the risk of heart failure, atrial fibrillation (AF), chronic kidney disease (CKD), peripheral artery disease (PAD), and cognitive decline [15].

Similarly, obesity is a well-documented risk factor for cardiovascular diseases. In a meta- analysis conducted by the Global Burden of Disease Study, obesity was found to significantly elevate the risk of coronary artery disease and stroke, particularly in populations with poor access to healthcare [16].

Diabetes is another critical factor in CVD outcomes. Studies have shown that individuals with diabetes are twice as likely to develop heart disease or have a stroke compared to those without the condition [17]. This elevated risk is primarily due to the increased likelihood of developing high blood sugar levels, which can damage the blood vessels and lead to atherosclerosis [18].

The Framingham Heart Study, an enduring source of longitudinal data on cardiovascular health, highlights the impact of diabetes as a predictor of cardiovascular events, as demonstrated by Kannel and McGee [19]. Their findings underscore metabolic health's importance in CVD risk, adding another layer to prevention strategies, especially for populations with high diabetes prevalence. Similarly, research by Mensah et al. [6] discusses the global burden of CVD and emphasizes preventive health measures for high-risk populations, stressing that addressing these risk factors can yield significant reductions in CVD incidence.

Further reinforcing the role of lifestyle choices, Ford et al. [20] demonstrate the protective effect of healthy behaviors on all-cause mortality, including CVD mortality, in U.S. adults. Their findings indicate that maintaining a healthy weight, abstaining from smoking, moderating alcohol intake, and engaging in regular physical activity can lower CVD mortality, supporting public health efforts focused on lifestyle modification. Roth et al. [21] add that such targeted interventions are essential given the variations in modifiable risk factors' impact across global regions, calling for tailored intervention strategies to effectively address localized CVD burdens. Finally, gender-specific research by Stampfer et al. [22] presents dietary and lifestyle factors as crucial to coronary heart disease prevention in women, advocating for gender-sensitive approaches in public health programs to maximize intervention efficacy. This aligns with the insights from Murray and Lopez [23] study on the global burden of disease, which illustrates how factors like high BMI and smoking amplify CVD risks, urging health organizations to prioritize lifestyle-centered preventive measures.

Collectively, these studies reveal a consensus that modifiable factors such as diet, physical activity, and smoking play significant roles in CVD risk. They advocate for preventive public health strategies that address these factors to lower CVD prevalence and promote cardiovascular health globally. The current study builds upon this foundation by investigating how a range of modifiable risk factors, including BMI, STP, sleeping time, smoking, and alcohol, contribute to CVD using a multivariable approach. Insights from this research aim to inform effective, targeted interventions for at-risk populations.

Despite these findings, there remains a need for more research focusing on specific populations and regions, particularly to understand socioeconomic factors such as income, and edu- cation with traditional CVD risk factors. By examining data from a diverse population like the BRFSS dataset, this study aims to fill this gap in the literature.

3. Methodology

The dataset used for this study is the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is a vital tool in public health surveillance, focusing on adults aged 18 and older who do not reside in institutional settings. It often serves as the sole source of state- or territory-specific data on risk behaviors. This information is invaluable to policymakers, researchers, academics, and the general public, supporting informed decision-making and public health initiatives.

To assess associations for binary outcomes, multiple logistic regression models were employed, adjusting for demographic and socioeconomic factors, including income, and residence (urban versus rural). Residence was coded as 1 for urban and 0 for rural.

3.1. Study Design and Data Source

This study utilized cross-sectional data from the Behavioral Risk Factor Surveillance System (BRFSS), collected in 2020. The BRFSS is a nationwide telephone-based survey conducted by the Centers for Disease Control and Prevention (CDC), gathering information on health-related risk behaviors, chronic health conditions, and use of preventive services from adults in the United States. The dataset includes variables on demographics, socioeconomic factors, and self-reported health behaviors, making it ideal for investigating the relationships between modifiable risk factors and CVD outcomes.

3.2. Study Population

The total study population, after addressing missing values, removing duplicate entries, and resolving data inconsistencies, consists of 203,326 individuals. These individuals are divided into two distinct age groups: 120,175 individuals aged 45 and older, representing 59.1% of the total population, and 83,151 individuals aged 18 to 44, accounting for 40.9%.

Gender distribution reveals that the study population includes 104,154 males (51.2%) and 99,172 females (48.8%), reflecting a nearly balanced representation of sexes. In terms of racial composition, the majority racial group (White) comprises 145,034 individuals (71.3% of the total population), while minority racial groups account for 58,292 individuals, making up 28.7%.

Residential settings indicate that the majority of participants reside in urban areas, with 173,985 individuals (85.6%) categorized as urban residents. In contrast, 29,341 individuals (14.4%) live in rural areas.

These descriptive statistics offer a comprehensive overview of the demographic characteristics of the population, providing a foundation for analyzing the prevalence of cardiovascular disease (CVD) and associated risk factors. The data highlight important distinctions by age, gender, race, and residential setting, which are crucial for understanding disparities in health outcomes and developing targeted public health interventions.

3.3. Variables

The outcome variable in this study is incident cardiovascular disease (CVD), defined by self-reported data on heart disease. The study will analyze both modifiable and non-modifiable risk factors as independent variables. Modifiable risk factors include body mass index (BMI), use of smokeless tobacco products (STP), current smoking status, physical activity, sleep duration, and alcohol consumption. These factors represent behaviors and conditions that individuals can potentially change to reduce their risk of developing CVD.

Non-modifiable risk factors, on the other hand, include age, sex, race/ethnicity, and residential area (urban or rural). These variables are intrinsic to individuals and cannot be altered, but they play a crucial role in determining CVD risk. Understanding these unchangeable characteristics can help target preventive measures more effectively.

Additionally, socioeconomic and demographic variables, such as education level, income level, and geographic region, will be assessed. These factors provide valuable context for understanding how broader social and economic conditions influence the risk of CVD. By examining these variables, the study aims to offer a comprehensive view of the risk factors associated with cardiovascular disease.

3.4. Statistical Analysis

Multiple Logistic Regression: Logistic regression models were employed to examine the associations between modifiable risk factors and binary outcomes, such as CVD diagnosis. The analysis adjusted for key demographic and socioeconomic factors, including income, and urban versus rural residence. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to quantify the strength and direction of associations for each risk factor.

All statistical analyses were conducted in Python, utilizing libraries such as stats models for logistic regression. Statistical significance was determined at a threshold of $p<0.05$ for all tests.

4. Result and Interpretation

The study investigated the relationship between cardiovascular disease (CVD) and several demographic factors, such as age, sex, race, and residence (urban vs. rural), using the BRFSS dataset. The results provided insights into how these factors contribute to CVD prevalence in the population.

4.1. Descriptive statistic on the data

The table below summarizes the prevalence of CVD across various demographic characteristics, integrating updated data on the number of cases and population distributions.

Table 1 Prevalence of Cardiovascular Disease (CVD) by Demographic Characteristics

Demographic Characteristic	Category	Total Population	CVD Cases	Prevalence (%)
Age	18–44 years	69,524	525	0.75
	45+ years	100,458	8,293	8.26
Gender	Male	87,574	5,677	6.48
	Female	82,408	3,141	3.81
Race	White	121,329	7,222	5.95
	Minority	48,653	1,596	3.28
Residential Setting	Urban	145,160	7,394	5.09
	Rural	24,822	1,424	5.74

4.2. Interpretation

- **Age:** Individuals aged 45 years and older have a significantly higher prevalence of CVD (8.26%) compared to those aged 18–44 years (0.75%). This reinforces existing research identifying age as a major risk factor for CVD.
- **Gender:** Men exhibit a higher prevalence of CVD (6.48%) compared to women (3.81%).
- **Race:** White individuals have a higher prevalence of CVD (5.95%) than minority groups (3.28%). Socioeconomic factors, healthcare access, and genetic predispositions may contribute to these disparities.
- **Residential Setting:** Rural residents exhibit a slightly higher prevalence of CVD (5.74%) compared to urban residents (5.09%).

4.3. Result and analysis using a Generalized Linear Model (GLM)

This research explored the associations between demographic, socioeconomic, and lifestyle factors and the risk of cardiovascular disease (CVD) using a Generalized Linear Model (GLM) with a logit link function. The findings provide valuable insights into the key predictors of CVD, offering a deeper understanding of the factors driving its incidence within the population.

4.3.1. Generalized Linear Model

Table 2.a Summary Statistics of Generalized Linear Model for Cardiovascular Disease (CVD)

Dep. Variable:	**CVD**	**No. Observation:**	**169982**
Model:	GLM	Df. Residuals:	169974
Model Family:	Binomial	Df. Model:	7
Link Function:	Logit	Scale	1.0000
Method:	IRLS	Log-Likelihood	-30844
Date	Nov. 26, 2024	Deviance:	61689
No. Iterations:	8	Pearson Chi2:	1.78e+05
Covariance Type:	Nonrobust	Pseudo R-Squ. (CS)	0.04409

Table 2.b Generalized Linear Model (GML) Coefficients for Predictors of Cardiovascular Disease (CVD)

	Coef	**Std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
Constant	-5.8838	0.067	-88.196	< 0.001	-6.015	-5.753
Age	2.3402	0.046	51.354	< 0.001	2.251	2.430
Sex	0.6569	0.024	27.949	< 0.001	0.611	0.703
Education	-0.0419	0.011	-3.834	< 0.001	-0.063	-0.020
Race	0.4375	0.029	15.162	< 0.001	0.381	0.494
Smoker	0.0868	0.029	3.039	0.002	0.031	0.143
STP	-0.2367	0.056	-4.200	< 0.001	-0.347	-0.126
Exercise	-0.4474	0.024	-18.761	< 0.001	-0.494	-0.401
Alcohol	0.4600	0.023	19.986	< 0.001	0.415	0.505

Interpretation of GLM Results for Cardiovascular Disease (CVD)

The analysis was conducted using a Generalized Linear Model (GLM) with a logit link function to examine the associations between various demographic, socioeconomic, and lifestyle factors and the likelihood of cardiovascular disease (CVD). The results of the model are as follows:

4.3.2. Model Fit

- **Log-Likelihood (-30,844):** The log-likelihood value represents the probability of observing the given data under the specified model parameters. A more negative log-likelihood, as seen here, reflects the large size of the dataset rather than a poor model fit. It is useful as a comparative measure for assessing model adequacy relative to alternative models.
- **Pseudo R-squared (0.04409):** This value indicates that approximately 4.4% of the variability in CVD occurrence is explained by the predictors included in the model. Although this is relatively low, it aligns with expectations for epidemiological studies where many unmeasured factors contribute to disease variability.
- **Deviance (61,689):** The deviance measures the goodness of fit, with lower values indicating a closer fit of the model to the observed data. The reported deviance suggests a reasonable fit for this model, considering the large sample size and the complexity of factors influencing CVD risk.

Significant Predictors of Cardiovascular Disease (CVD)

The GLM regression results presented above explore the role of modifiable risk factors in the incidence of cardiovascular disease (CVD). This analysis uses a binomial logistic regression model, with the outcome variable being the diagnosis of CVD. The model was adjusted for multiple demographic, lifestyle, and behavioral factors to assess their independent effects on CVD risk.

4.3.3. Key Findings

- Age (Coef = 2.3402, p < 0.001)
  - Odds Ratio (OR) = 10.42: Age remains the most significant predictor of CVD in this model. Individuals aged 45 and older have over 10 times the odds of developing CVD compared to those aged 18–44. This underlines the critical role of age in CVD risk, with older individuals being at significantly higher risk.
- Sex (Coef = 0.6569, p < 0.001)
  - Odds Ratio (OR) = 1.93: Men are nearly twice as likely to develop CVD compared to women. This finding suggests that gender plays a significant role in CVD outcomes, with men being more prone to cardiovascular risks.
- Race (Coef = 0.4375, p < 0.001)
  - Odds Ratio (OR) = 1.55: Individuals from minority racial groups are at a higher risk of developing CVD compared to white individuals. This highlights the influence of racial disparities in CVD outcomes, with racial minorities being more vulnerable to cardiovascular diseases.
- Smoking (Coef = 0.0868, p = 0.002)

- Odds Ratio (OR) = 1.09: Smoking is positively associated with CVD risk. Smokers are at a significantly higher risk of developing cardiovascular diseases compared to non-smokers. The small but statistically significant coefficient indicates that even a slight increase in smoking prevalence has a measurable effect on CVD risk.

- Smokeless Tobacco Products (STP) (Coef = -0.2367, $p < 0.001$)
  - Odds Ratio (OR) = 0.79: Interestingly, the use of smokeless tobacco products is negatively associated with CVD in this model. While unexpected, this finding may warrant further investigation, as it suggests that individuals using STP have lower odds of developing CVD compared to non-users. This could be related to confounding variables or the specific characteristics of the study population.
- Exercise (Coef = -0.4474, $p < 0.001$)
  - Odds Ratio (OR) = 0.64: Regular exercise is strongly protective against CVD. Those who engage in physical activity have 36% lower odds of developing CVD, emphasizing the importance of exercise as a modifiable factor in cardiovascular health.
- Alcohol Consumption (Coef = 0.4600, $p < 0.001$)
  - Odds Ratio (OR) = 1.58: Alcohol consumption is positively associated with an increased risk of CVD. Individuals who drink alcohol are 58% more likely to develop CVD compared to those who abstain, underlining the negative effects of alcohol on cardiovascular health.

This statistical analysis highlights the significant role of modifiable risk factors in cardiovascular disease outcomes. The most influential factors are age, sex, race, smoking, exercise, and alcohol consumption. The results reinforce the need for targeted public health interventions focusing on lifestyle modifications, such as smoking cessation, regular exercise, and alcohol moderation, to reduce the burden of CVD. Additionally, further research is needed to explore the counterintuitive finding regarding smokeless tobacco products and to better understand the complex interactions between these risk factors.

5. Discussion

This study explored the relationship between cardiovascular disease (CVD) and modifiable risk factors using a generalized linear model (GLM) on data from the Behavioral Risk Factor Surveillance System (BRFSS). The analysis revealed that age, sex, race, smoking, alcohol consumption, exercise, and residential setting significantly predicted CVD outcomes. Age stood out as the strongest risk factor, with individuals aged 45 and above exhibiting over 10 times higher odds of developing CVD compared to younger adults. Men demonstrated a higher prevalence of CVD compared to women, while white individuals had greater odds of CVD than minority groups, possibly due to differences in socioeconomic factors, healthcare access, and genetic predispositions.

Lifestyle behaviors, including smoking, alcohol use, and exercise, were significantly associated with CVD. Smoking and alcohol consumption increased the risk, while regular exercise was protective. Interestingly, rural residents faced slightly higher CVD risks than their urban counterparts, potentially due to disparities in healthcare access and lifestyle differences.

These findings underscore the critical role of modifiable risk factors in CVD outcomes. Tailored public health strategies, including promoting regular exercise, reducing smoking and alcohol use, and addressing healthcare disparities, are essential. Interventions targeting older adults, men, and rural populations may be particularly effective in mitigating CVD incidence and improving overall cardiovascular health. This study highlights the importance of comprehensive, targeted approaches in reducing the public health burden of CVD.

6. Conclusion

This study highlights the significant impact of demographic, lifestyle, and behavioral factors on cardiovascular disease (CVD) risk, with age, sex, race, smoking, alcohol consumption, and physical activity emerging as key predictors. Notably, older individuals, men, smokers, and alcohol consumers exhibited higher odds of CVD, whereas regular exercise showed a protective effect. These findings reinforce the need for targeted public health interventions to mitigate CVD risks through lifestyle modifications and healthcare accessibility improvements. This research provides valuable insights for policymakers and healthcare practitioners, contributing to the development of preventive strategies that enhance cardiovascular health and reduce disease burden in society.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflicts of interest related to this research.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

Disclaimer

The views expressed in this article are those of the authors and do not necessarily represent the official policies or positions of any affiliated institutions.

Authorship

All authors contributed equally to the conceptualization, writing, and editing of this article without any external writing assistance.

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