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ORIGINAL RESEARCH

Sex Differences in the Relationship Between Self-Reporting of Snoring and Cardiovascular Risk: An Analysis of NHANES

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Background: Identifying risk factors for cardiovascular disease (CVD) is critical for effective prevention and management. While classic CVD risk factors have been extensively studied, there is a scarcity of research on the association between snoring and CVD risk, particularly in the context of sex differences.

Methods: This study utilized data from the National Health and Nutrition Examination Survey (NHANES) conducted between 2015 and 2020. Participants were initially categorized based on the severity of snoring or the presence of snoring.Within the snoring group, they were further classified by sex. Analysis was carried out using multivariate logistic regression.

Results: Our study included 12,681 participants aged 18 years or older. When compared to the non-snoring group, individuals in the moderate snoring group had a higher odds ratio (OR) of 1.418 (95% CI 1.083 to 1.857, $p = 0.011$), while those in the severe snoring group had a higher OR of 1.882 (95% CI 1.468 to 2.409, $p < 0.001$). In the snoring group, individuals were further categorized by gender: 4527 males and 4131 females. Importantly, male patients showed a higher OR for atrial fibrillation (4.945, 95% CI 1.187 to 20.598, $p = 0.028$) compared to females. Additionally, male patients had a higher OR for coronary heart disease (2.002, 95% CI 1.152 to 3.479, $p = 0.014$) compared to females.

Conclusion: Sex plays a significant role in the relationship between snoring and CVD risk. Males with snoring have a higher risk of developing CVD compared to females. In particular, male snorers are nearly five times more likely to develop atrial fibrillation and about twice as likely to experience coronary artery disease in comparison to female snorers. It is recommended that healthcare providers and public health officials prioritize cardiovascular risk assessments for male individuals who exhibit symptoms of snoring.

Keywords: gender differences, snoring, cardiovascular risk, atrial fibrillation, coronary artery disease

Introduction

Cardiovascular disease (CVD) is the leading cause of death, accounting for one-third of all mortality causes.[1] CVD remains the leading cause of death in the United States population, and over the past 18 years, CVD has claimed the lives of more than 10 million individuals.[1] CVD pose a significant health burden globally, accounting for a substantial number of deaths and disabilities.[2] Identifying and understanding the risk factors and management of these conditions.[3] The relationship between sleep apnea and cardiovascular disease is well established.[4] However, studies on the relationship between snoring and cardiovascular disease are relatively scarce. Among patients with sleep apnea, 94% experience snoring, while approximately 43% of snorers are at risk for sleep apnea.[4–6] A substantial proportion of the general population (10% to 60%) are habitual snorers, but most do not have sleep apnea.[7] Compared to sleep apnea, snoring is easier to diagnose and more readily accepted by the public.[5] Therefore, exploring the relationship between snoring and cardiovascular disease may be more meaningful. Hence, our study is conducted among snorers. Previous studies have confirmed that snoring can increase the risk of endothelial dysfunction and diabetes, as well as elevate sympathetic nervous system excitability.[8–10] This may be a significant reason why snoring raises the risk of cardiovascular diseases.

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Moreover, even among the existing studies that have examined the association between snoring and CVD risk, the findings are contradictory.[11,12] Therefore, it is essential to explore the relationship between snoring and CVD.

Disparities between men and women persist in the diagnosis, treatment, and prognosis of CVD.[13] The in-hospital mortality rate for female patients with acute coronary syndrome is significantly higher than that of male patients.[14] Research has indicated that women are more likely to experience complications, including bleeding, associated with coronary revascularization procedures.[15] During midlife, around the time of peri- and post-menopause, sleep quality deteriorates, while CVD risk significantly increases in women compared to earlier decades.[16] One of the most notable biological differences is the influence of sex hormones. Estrogen, which is more prevalent in premenopausal women, has been shown to have protective effects against CVD.[17] It helps to maintain healthy lipid profiles, reduces inflammation, and improves endothelial function.[17] Males tend to accumulate visceral fat, which is associated with a higher risk of metabolic syndrome and cardiovascular complications.[18] The findings of these studies underscore the significant role of sex in CVD. Moreover, socioeconomic status and lifestyle have an impact on cardiovascular disease.[19] Lower socio-economic status is associated with higher rates of smoking, obesity, and limited access to healthcare services, all of which contribute to increased CVD risk.[19] Men are more likely to engage in behaviors that increase CVD risk, such as heavy drinking and unhealthy eating patterns.[20] Therefore, exploring gender differences in the association between snoring and cardiovascular disease risk can inform the development of health policies and guidelines, thereby improving overall cardiovascular disease outcomes.[21] However, there is a lack of research examining sex differences in the connection between snoring and CVD risk. Therefore, it is particularly important to investigate these sex differences.

The present study aimed to investigate the sex differences in the association between snoring and CVD risk using data from the National Health and Nutrition Examination Survey (NHANES), a nationally representative sample in the United States.

Method

Study Population

The NHANES is an ongoing research program that provides population estimates related to the nutrition and health of adults and children in the United States. The survey utilizes a stratified, multistage probability design to recruit a representative sample of the U.S population. Data for the survey are obtained through personal structured interviews conducted at participants' homes, health examinations conducted at a mobile examination center, and laboratory analysis of specimens.[22] All data can be found on the NHANES website (http://www.cdc.gov/nchs/nhanes.htm). The study protocols were approved by the Institutional Review Board (IRB) of the National Center for Health Statistics, and written informed consent was obtained from each participant. Due to the combination of data from 2017–2018 with that of 2019–2020, the 2017–2018 data has been excluded. Our study included all participants in the NHANES from 2015 through 2020 who were 18 years of age or older and had available sleep data that included information on snoring. We were excluded participants under the age of 18 and those with incomplete key data.

Grouping Methods

In this study, we employed two grouping methods. The first method involved dividing participants into two groups based on the presence or absence of snoring. The second method involved classifying participants into five groups based on the severity of snoring: non-snoring group, mild snoring group, moderate snoring group, severe snoring group, and unclear snoring group. Within the population of individuals who reported snoring, we divided them into two groups based on their gender: male snorers and female snorers.

Medication Usage and Disease Definition

Participants were queried about their recent use of prescription medications within a 30-day period. Respondents who acknowledged taking such medications were asked to furnish the interviewers with the respective containers. If the containers were not accessible, participants were requested to disclose the names of the medications to the researchers. In this study, the presence of atrial fibrillation was determined if the investigator reported taking atrial fibrillation medication and provided evidence. For diabetes, the diagnosis was based on medication usage, blood glucose and

HbA1c values, and past medical history. Hypertension was considered present if the blood pressure was consistently equal to or greater than 140/90 mmHg on three times or if the patient was currently taking hypertension medication or had a documented history of hypertension.

Sociodemographic Characteristics and Snore Status

The study collected data on various sociodemographic characteristics and weight status of the participants. These included:1.Age: Participants reported their age. 2. Sex: Participants identified themselves as male or female. 3. Race and Ethnic Group: Participants identified their racial and ethnic background, including options such as Mexican American, Other Hispanic, non-Hispanic White, non-Hispanic Black, Non-Hispanic Asian, or other.4. Education: Participants reported their educational attainment, categorized as less than 11th grade, high school, some college, college graduate, or other.5. Family Income: Participants provided information about their family income, categorized as less than 1.3 of the federal poverty level, 1.3 to 3.49 of the federal poverty level, or equal to or greater than 3.5 of the federal poverty level.6.Drinking Status: Participants reported their smoking status as nondrinker, low-to-moderate drinker (<=2 drinks/day in men and <=1 drink/day in women), or heavy drinker (>2 drinks/day in men and >1 drinks/day in women).7.Smoking Status: Participants reported their smoking status as current smoker, former smoker, or never smoked. Individuals who reported smoking more than 100 cigarettes in their lifetime were classified as current smokers, while those who reported smoking more than 100 cigarettes but had quit smoking were classified as former smokers. 8. Snore Status: Participants were queried about the frequency of their snoring over the past 12 months during sleep. In cases where participants were unable to provide an answer, inquiries were made to other household members, including bed partners, regarding the snoring behavior. Participants reported their snore status as never, rarely snore, occasionally snore, frequently snore, or do not know snore. Individuals who reported snoring 1–2 nights a week were classified as rarely snore, while those who reported snoring 3–4 nights a week were classified as occasionally snore. Those who reported snoring 5 or more nights a week were classified as frequently snore, and those who reported not knowing whether they snore were classified as do not know snore. In addition to sociodemographic characteristics, weight status was assessed using body mass index (BMI), calculated as the weight in kilograms divided by the square of the height in meters. Participants were then classified into three weight-status groups: normal weight (BMI < 25), overweight (BMI 25 to <30), or obese (BMI ≥ 30).

Outcome Events

This study defined CVD events as including coronary heart disease, angina, atrial fibrillation, heart failure, stroke, heart attack, and hypertension.

Statistical Analysis

Percentages, means, and 95% confidence interval of key variables were calculated to describe the sample at each level of snoring. Logistic regression model was employed to examine the association between snoring and the outcome variables, while accounting for potential confounding variables. This logistic regression aimed to address any imbalances in potential confounding variables between the groups, thereby reducing their influence on the outcome measures.

The data analysis was conducted using V.15.1 (Stata Corp LP), incorporating survey analysis procedures to account for the complex sampling design. The survey examination weights were applied as appropriate to ensure the obtained estimates were nationally representative. In instances where data was absent for the primary variable, snoring, cases were excluded. For missing data pertaining to covariates, categorical variables with missing data were consolidated into a single category, while multiple imputation was employed for continuous variables. The utilization of multiple imputation was intended to enhance the comprehensiveness and precision of the analysis, while mitigating potential biases stemming from missing data. All statistical tests conducted were two-sided, and a significance level of $P < 0.05$ was considered statistically significant. To ensure adequate statistical power, we estimated the sample size. Statistical analyses were conducted using appropriate tests, and corrections for multiple hypothesis testing were implemented. Effect sizes were estimated based on findings from previous similar studies. The probabilities of type II errors were set at 0.20. Special attention was paid to subgroups, where the risk of Type II errors might be elevated, to ensure the robustness of the analysis.

Results

Study Population

Out of the 12,681 participants, a total of 3113 individuals who reported no snoring were included in the study based on the questionnaire survey regarding the presence of snoring in Table 1. Among the participants, there were 3009 individuals categorized as mild snorers, 2245 individuals categorized as moderate snorers, 3404 individuals categorized as severe snorers, and 910 individuals categorized as unclear snorers. The baseline data divided into two groups based on the presence or absence of snoring is presented in Table S1. A total of 4023 individuals were classified as the non-snoring group, while 8658 individuals were classified as the snoring group. In the snoring group, individuals were further categorized by gender: 4527 males and 4131 females (Table S2).

Relationship of Snoring to Cardiovascular Risks

In the unadjusted logistic regression model1, the odds ratios (OR) for moderate snoring (OR 1.569, 95% CI 1.335 to 1.843, P < 0.001), and severe snoring (OR 2.199, 95% CI 1.900 to 2.545, P < 0.001) are presented in Table 2. In the adjusted logistic regression Model 2, which controlled for variables such as sex, race, age, education, and marital status, the odds ratios (OR) for mild snoring, moderate snoring, and severe snoring were 1.096 (95% CI 0.934 to 1.286, P = 0.262), 1.382 (95% CI 1.161 to 1.644, P < 0.001), and 1.937 (95% CI 1.646 to 2.279, P < 0.001) respectively (Table 2 - Model 2). In the multivariable logistic regression Model 3, adjusted for variables including sex, race, age, education, marital status, creatinine (Cr), triglyceride (TG), uric acid (UA), total cholesterol (TC), high-density lipoprotein cholesterol (HDL), and low-density lipoprotein cholesterol (LDL), individuals in the moderate snoring group had an odds ratio (OR) of 1.418 (95% CI: 1.083 to 1.857, p = 0.011) compared to the non-snoring group. Similarly, individuals in the severe snoring group had an odds ratio (OR) of 1.882 (95% CI: 1.468 to 2.409, p < 0.001) (Table 2-Model 3). Individuals who snored had a higher odds ratio compared to non-snorers (Table S3).

Gender Differences in the Association Between Snoring and Cardiovascular Risk

Males with snoring demonstrated a higher incidence rate of CVD (OR 1.414, 95% CI 1.099–1.819, p=0.007) in comparison to females (Table 3). The odds ratios (OR) for male patients with snoring were higher than those for females in various CVDs, including atrial fibrillation (OR 3.441, 95% CI 1.513 to 7.827, p = 0.003), coronary heart disease (OR 2.019, 95% CI 1.409 to 2.892, p < 0.001), heart disease (OR 1.682, 95% CI 1.207 to 2.344, p = 0.002), angina (OR 1.468, 95% CI 0.990 to 2.175, p = 0.055), hypertension (OR 1.159, 95% CI 1.022 to 1.314, p = 0.021), and heart failure (OR 1.225, 95% CI 0.879 to 1.707, p = 0.229) (Figure 1). However, for stroke patients, the odds ratio (OR) for males was lower than that for females (OR 0.850, 95% CI 0.609 to 1.186, p = 0.339) (Figure 1).

After adjusting for variables such as race, age, education, and marital status, male patients exhibited a higher odds ratio (OR 1.444, 95% CI 1.260 to 1.654, p <0.001) for CVD compared to females (Table 3). The odds ratios (OR) for male patients with snoring were higher than those for females in various CVD, including atrial fibrillation (OR 3.213, 95% CI 1.474 to 7.006, p = 0.003), coronary heart disease (OR 2.639, 95% CI 1.759 to 3.957, p < 0.001), heart disease (OR 2.209, 95% CI 1.532 to 3.187, p < 0.001), angina (OR 1.877, 95% CI 1.244 to 2.833, p = 0.003), hypertension (OR 1.279, 95% CI 1.117 to 1.464, p < 0.001), and heart failure (OR 1.676, 95% CI 1.203 to 2.334, p = 0.002) (Figure 2). However, for stroke patients, the odds ratio (OR) for males was lower than that for females (OR 0.987, 95% CI 0.689 to 1.415, p = 0.945) (Figure 2).

After adjusting for race, age, education, marital status, Cr, TG, UA, TC, HDL, and LDL, male patients exhibited a higher odds ratio (OR 1.414, 95% CI 1.099–1.819, p = 0.007) for CVD compared to females (Table 3). After adjusting for race, age, education, marital status, Cr, TG, UA, TC, HDL, and LDL, male patients showed a higher odds ratio for hypertension (HTN) (1.358, 95% CI 1.051 to 1.755, p = 0.021) compared to females (Figure 3). After adjusting for race, age, income, marital status, diabetes, education, heart failure (HF), angina, BMI, coronary heart disease (CHD), heart attack (HA), HTN, Cr, TG, UA, TC, HDL, and LDL, male patients exhibited a higher odds ratio for atrial fibrillation (4.945, 95% CI 1.187 to 20.598, p = 0.028) compared to females (Figure 3). After adjusting for race, age, income, marital, diabetes, education, angina, marital, HTN, BMI, HA, Cr, TG, UA, TC, HDL, and LDL, Male patients exhibited

Table 1 Baseline Characteristics of Study Participants in NHANES 2015–2020 Grouped According to Snoring Severity

	Snoring					P
	Non-Snoring	**Mild Snoring**	**Moderate Snoring**	**Severe Snoring**	**Nuclear Snoring**	
Total No. of participants	3113	3009	2245	3404	910	
Creatinine(mmol/L)	72.958 (72.112 to 73.814)	74.302 (73.499 to 75.114)	75.383 (74.514 to 76.262)	76.569 (75.777 to 77.370)	76.819 (75.202 to 78.471)	<0.001
Sodium(mmol/L)	139.656 (139.560 to 139.752)	139.807 (139.714 to 139.899)	139.748 (139.633 to 139.863)	139.803 (139.711 to 139.896)	139.658 (139.477 to 139.840)	0.121
Triglyceride(mmol/L)	1.220 (1.195 to 1.246)	1.304 (1.276 to 1.333)	1.398 (1.365 to 1.432)	1.565 (1.533 to 1.597)	1.356 (1.305 to 1.409)	<0.001
Uric acid(mmol/L)	293.005 (289.967 to 296.074)	305.642 (302.571 to 308.744)	315.724 (312.182 to 319.307)	326.499 (323.545 to 329.481)	310.745 (305.170 to 316.423)	<0.001
Total cholesterol(mmol/L)	4.637 (4.600 to 4.675)	4.738 (4.700 to 4.776)	4.742 (4.698 to 4.785)	4.812 (4.775 to 4.849)	4.750 (4.681 to 4.820)	<0.001
High-density lipoprotein cholesterol(mmol/L)	1.407 (1.392 to 1.423)	1.359 (1.345 to 1.374)	1.322 (1.306 to 1.339)	1.236 (1.224 to 1.248)	1.354 (1.327 to 1.381)	<0.001
Low-density lipoprotein cholesterol(mmol/L)	2.585 (2.538 to 2.633)	2.691 (2.644 to 2.739)	2.719 (2.663 to 2.777)	2.795 (2.748 to 2.843)	2.695 (2.606 to 2.787)	<0.001
Gender						<0.001
Female	1838 (59.043%)	1583 (52.609%)	1110 (49.443%)	1438 (42.244%)	503 (55.275%)	
Male	1275 (40.957%)	1426 (47.391%)	1135 (50.557%)	1966 (57.756%)	407 (44.725%)	
Age						<0.001
18–44 years	1530 (49.149%)	1451 (48.222%)	831 (37.016%)	1216 (35.723%)	253 (27.802%)	
45–64 years	842 (27.048%)	1012 (33.632%)	868 (38.664%)	1470 (43.184%)	311 (34.176%)	
≥65 years	741 (23.803%)	546 (18.146%)	546 (24.321%)	718 (21.093%)	346 (38.022%)	
Race						<0.001
Mexican American	330 (10.601%)	411 (13.659%)	284 (12.650%)	567 (16.657%)	133 (14.615%)	
Other Hispanic	333 (10.697%)	310 (10.302%)	247 (11.002%)	466 (13.690%)	95 (10.440%)	
Non-Hispanic White	1130 (36.299%)	1046 (34.762%)	791 (35.234%)	1074 (31.551%)	334 (36.703%)	
Non-Hispanic Black	784 (25.185%)	711 (23.629%)	582 (25.924%)	797 (23.414%)	237 (26.044%)	
Non-Hispanic Asian	410 (13.171%)	385 (12.795%)	242 (10.780%)	344 (10.106%)	80 (8.791%)	
Other	126 (4.048%)	146 (4.852%)	99 (4.410%)	156 (4.583%)	31 (3.407%)	
Education						<0.001
Less than 11th grade	611 (19.627%)	507 (16.849%)	360 (16.036%)	806 (23.678%)	249 (27.363%)	
High school	721 (23.161%)	679 (22.566%)	529 (23.563%)	805 (23.649%)	224 (24.615%)	
Some college	987 (31.706%)	941 (31.273%)	744 (33.140%)	1087 (31.933%)	267 (29.341%)	
College graduate	785 (25.217%)	879 (29.212%)	610 (27.171%)	705 (20.711%)	165 (18.132%)	
Other	9 (0.289%)	3 (0.100%)	2 (0.089%)	1 (0.029%)	5 (0.549%)	
Marital status						<0.001
Never married	1477 (47.446%)	1796 (59.688%)	1371 (61.069%)	2087 (61.310%)	259 (28.462%)	
Married or living with partner	524 (16.833%)	378 (12.562%)	325 (14.477%)	548 (16.099%)	306 (33.626%)	
Divorced, separated, or widowed	597 (19.178%)	474 (15.753%)	307 (13.675%)	421 (12.368%)	213 (23.407%)	
Other	515 (16.544%)	361 (11.997%)	242 (10.780%)	348 (10.223%)	132 (14.505%)	
Ratio of family income to poverty level						<0.001
≤1.3 of the federal poverty line	902 (28.975%)	694 (23.064%)	483 (21.514%)	949 (27.879%)	314 (34.505%)	
>1.3≤3.49 of the federal poverty line	1063 (34.147%)	1027 (34.131%)	835 (37.194%)	1187 (34.871%)	289 (31.758%)	
>3.5 of the federal poverty line	753 (24.189%)	968 (32.170%)	683 (30.423%)	875 (25.705%)	158 (17.363%)	
Other	395 (12.689%)	320 (10.635%)	244 (10.869%)	393 (11.545%)	149 (16.374%)	

(*Continued*)

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Table 1 (Continued).

	Snoring					P
	Non-Snoring	**Mild Snoring**	**Moderate Snoring**	**Severe Snoring**	**Nuclear Snoring**	
Diabetes	717 (23.032%)	667 (22.167%)	695 (30.958%)	1194 (35.076%)	316 (34.725%)	
BMI (kg/m2)						<0.001
<25	1251 (40.186%)	915 (30.409%)	482 (21.470%)	468 (13.749%)	248 (27.253%)	
25 to 30	939 (30.164%)	996 (33.101%)	772 (34.388%)	997 (29.289%)	289 (31.758%)	
30	884 (28.397%)	1082 (35.959%)	967 (43.073%)	1909 (56.081%)	363 (39.890%)	
Other	39 (1.253%)	16 (0.532%)	24 (1.069%)	30 (0.881%)	10 (1.099%)	
Cigarette use						<0.001
Never smoked	1928 (61.934%)	1867 (62.047%)	1313 (58.486%)	1757 (51.616%)	469 (51.538%)	
Former smoker	179 (5.750%)	151 (5.018%)	124 (5.523%)	223 (6.551%)	53 (5.824%)	
Current smoker	312 (10.022%)	301 (10.003%)	261 (11.626%)	407 (11.957%)	124 (13.626%)	
Other	694 (22.294%)	690 (22.931%)	547 (24.365%)	1017 (29.877%)	264 (29.011%)	
Alcohol use						<0.001
Never drinker	1206 (38.741%)	956 (31.771%)	706 (31.448%)	1135 (33.343%)	388 (42.637%)	
Low-to-moderate drinker	954 (30.646%)	1013 (33.666%)	817 (36.392%)	1144 (33.608%)	283 (31.099%)	
Heavy drinker	953 (30.614%)	1040 (34.563%)	722 (32.160%)	1125 (33.049%)	239 (26.264%)	

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Table 2 Snoring and Indicators of Cardiovascular Disease Risk Grouped According to the Severity of Snoring

	Model 1 OR (95% CI) P	Model 2 OR (95% CI) P	Model 3 OR (95% CI) P
Snoring			
Non-snoring	Reference	Reference	Reference
Mild snoring	1.086(0.934 to 1.261)0.284	1.096(0.934 to 1.286)0.262	1.066(0.836 to 1.361)0.606
Moderate snoring	1.569(1.335 to 1.843) <0.001	1.382(1.161 to 1.644) <0.001	1.418(1.083 to 1.857)0.011
Severe snoring	2.199(1.900 to 2.545) <0.001	1.937(1.646 to 2.279) <0.001	1.882(1.468 to 2.409) <0.001
Nuclear snoring	1.575(1.271 to 1.951) <0.001	1.088(0.867 to 1.366)0.467	0.959(0.673 to 1.368)0.817

Notes: Model1: unadjusted. Model2: means adjusted for sex, race, age, education, marital. Model3: means adjusted for sex, race, age, education, marital, creatinine, triglyceride, uric acid, total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol.

Table 3 Logistic Regression Analysis of the Association Between Snoring and Various Cardiovascular Diseases Stratified by Sex

	Model 1 OR (95% CI) P	Model 2 OR (95% CI) P	Model 3 OR (95% CI) P
Female	Reference	Reference	Reference
Male			
Cardiovascular disease[a]	1.271(1.122 to 1.442) <0.001	1.444(1.260 to 1.654) <0.001	1.414(1.099 to 1.819) 0.007
Hypertension[b]	1.159(1.022 to 1.314)0.021	1.279(1.117 to 1.464) <0.001	1.358(1.051 to 1.755)0.019
Atrial fibrillation[c]	3.441(1.513 to 7.827)0.003	3.213(1.474 to 7.006)0.003	4.945(1.187 to 20.598)0.028
Heart failure[d]	1.225(0.879 to 1.707)0.229	1.676(1.203 to 2.334)0.002	0.812(0.399 to 1.651)0.566
Coronary heart disease[e]	2.019(1.409 to 2.892) <0.001	2.639(1.759 to 3.957) <0.001	2.002(1.152 to 3.479)0.014
Stroke[f]	0.850(0.609 to 1.186)0.339	0.987(0.689 to 1.415)0.945	0.866(0.504 to 1.487)0.601
Angina[g]	1.468 (0.990 1to 2.175)0.055	1.877(1.244 to 2.833)0.003	1.625(0.697 to 3.779)0.261
Heart attack[h]	1.682(1.207 to 2.344)0.002	2.209(1.532 to 3.187) <0.001	1.723(1.054 to 2.817)0.030

Notes: Model 1: unadjusted. Model 2: adjusted for race, age, education, marital. [a]Cardiovascular diseases model 3 adjusted for sex, race, age, education, marital, body mass index (BMI), creatinine (Cr), triglyceride (TG), uric acid (UA), total cholesterol (TC), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL). [b]Hypertension adjusted for race, age, education, marital, BMI, Cr, TG, UA, TC, LDL, LDL. [c]Atrial fibrillation model 3 adjusted for race, age, income, marital, diabetes, education, hypertension (HTN), heart failure (HF), angina, marital, BMI, coronary heart disease (CHD), heart attack (HA), Cr, TG, UA, TC, HDL, LDL. [d]Heart failure model 3 adjusted for race, age, income, marital, diabetes, education, angina, marital, HTN, BMI, HA, Cr, TG, UA, TC, HDL, LDL. [e]Coronary heart disease model 3 adjusted for race, age, income, marital, diabetes, education, angina, marital, HF, BMI, HA, Cr, TG, UA, TC, HDL, LDL. [f]Stork model 3 adjusted for race, age, income, marital, education, diabetes, HTN, BMI, Cr, TG, UA, TC, HDL, LDL. [g]Angina model 3 adjusted for race, age, income, marital, education, diabetes, HTN, BMI, TG, UA, TC, HDL, LDL. [h]Heart attack model 3 adjusted for race, age, income, marital, diabetes, education, angina, marital, HTN, HF, BMI, CHD, Cr, TG, UA, TC, HDL, LDL.

a lower odds ratio for heart failure (0.812, 95% CI 0.399 to 1.651, p = 0.566) compared to females (Figure 3). Adjusted for race, age, income, marital status, diabetes, education, angina, BMI, heart attack, Cr, TG, UA, TC, HDL, and LDL, male patients exhibited a higher odds ratio for coronary heart disease (2.002, 95% CI 1.152 to 3.479, p = 0.014)

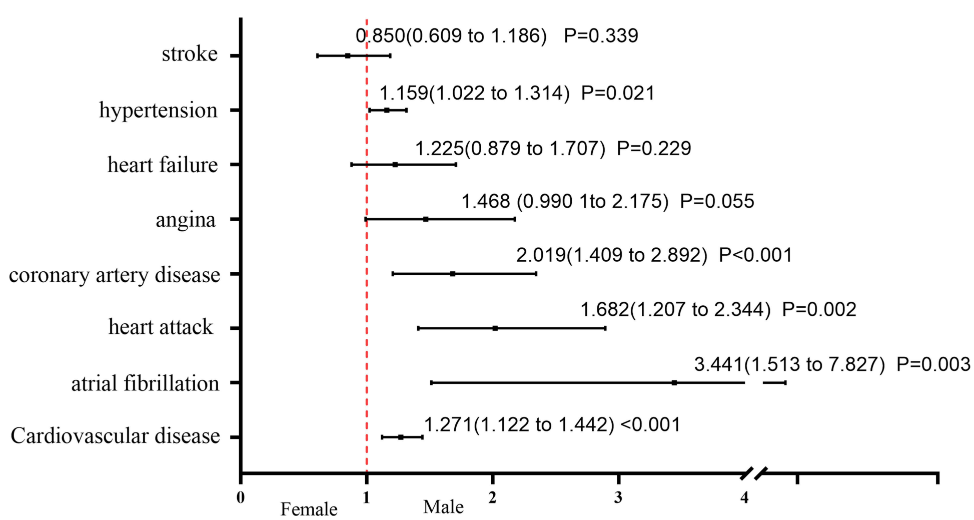

Figure 1 Unadjusted Logistic Regression Analysis of the Association Between Snoring and Various Cardiovascular Diseases Stratified by Sex.

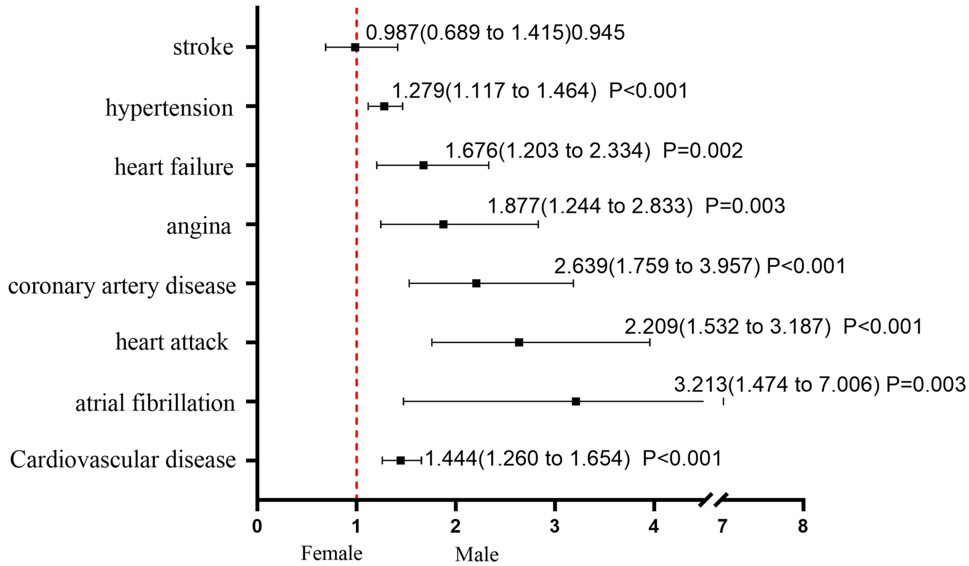

Figure 2 Adjusting for Race, Age, Education, and Marital Status: Association Between Snoring and Various Cardiovascular Diseases Stratified by Sex.

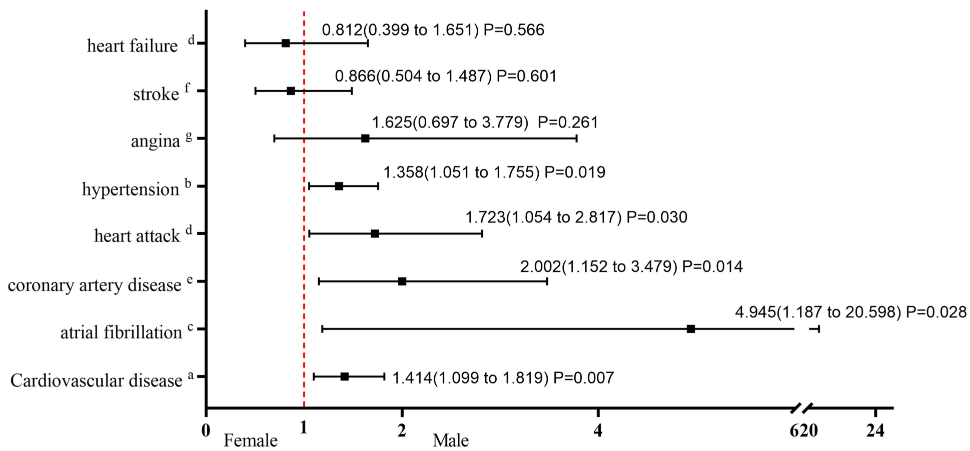

Figure 3 Adjusting for Potentially Relevant Variables: Association Between Snoring and Various Cardiovascular Diseases Stratified by Sex.

Notes: a: cardiovascular diseases model 3 adjusted for sex, race, age, education, marital, body mass index (BMI), creatinine (Cr), triglyceride (TG), uric acid (UA), total cholesterol (TC), high-density lipoprotein cholesterol (HDL), low-density lipoprotein cholesterol (LDL). b: hypertension adjusted for race, age, education, marital, BMI, Cr, TG, UA, TC, LDL, LDL. c: atrial fibrillation model 3 adjusted for race, age, income, marital, diabetes, education, hypertension (HTN), heart failure (HF), angina, marital, BMI, coronary heart disease (CHD), heart attack (HA), Cr, TG, UA, TC, HDL, LDL. d: heart failure model 3 adjusted for race, age, income, marital, diabetes, education, angina, marital, HTN, BMI, HA, Cr, TG, UA, TC, HDL, LDL. e: coronary heart disease model 3 adjusted for race, age, income, marital, diabetes, education, angina, marital, HF, BMI, HA, Cr, TG, UA, TC, HDL, LDL. f: stork model 3 adjusted for race, age, income, marital, education, diabetes, HTN, BMI, Cr, TG, UA, TC, HDL, LDL. g: angina model 3 adjusted for race, age, income, marital, education, diabetes, HTN, BMI, TG, UA, TC, HDL, LDL. h: heart attack model 3 adjusted for race, age, income, marital, diabetes, education, angina, marital, HTN, HF, BMI, CHD, Cr, TG, UA, TC, HDL, LDL.

compared to females (Figure 3).After adjusting for variables including race, age, income, marital, education, diabetes, HTN, BMI, Cr, TG, UA, TC, HDL, and LDL, male patients showed a decreased odds ratio for stroke (0.866, 95% CI 0.504 to 1.487, p = 0.601) in comparison to females (Figure 3). Adjusted for race, age, income, marital, education, diabetes, HTN, BMI, TG, UA, TC, HDL, and LDL, male patients exhibited a lower odds ratio for angina (1.625, 95% CI 0.697 to 3.779, p = 0.261) compared to females (Figure 3). Adjusted for race, age, income, marital, diabetes, education, angina, HTN, HF, BMI, CHD, Cr, TG, UA, TC, HDL, and LDL, male patients exhibited a lower odds ratio for heart attack (1.723, 95% CI 1.054 to 2.817, p = 0.261) compared to females (Figure 3).

Discussion

Notably, our study revealed that male patients who snore have a notably higher prevalence of CVD, including hypertension, atrial fibrillation, coronary heart disease, and heart disease, in comparison to their female counterparts. Specifically, the risk of atrial fibrillation in male snorers is almost five times greater than in female snorers. The risk of coronary heart disease is twice as high in male snorers compared to females. Additionally, male snorers have a higher risk of developing hypertension and heart disease compared to their female counterparts. These findings emphasize the importance of considering sex-specific factors in assessing CVD risk associated with snoring. This novel contribution expands our understanding of the complex relationship between snoring and CVD risk and highlights the need for further research to explore the underlying mechanisms driving these gender-specific differences.

Our study's findings are consistent with previous research, which underscores the potential role of snoring as a risk factor for CVD events.[23–25] Snoring, a common sleep disorder, is characterized by loud and intermittent sounds produced during sleep.[26] It has been linked to various health implications, including CVD such as HTN, CHD, and stroke.[27,28] Our study contributes to the existing literature by providing further evidence of the association between snoring and CVD risk. Snoring may predispose individuals to AF, which is the most common cardiac arrhythmia.[29,30] This can occur through various mechanisms, such as hypoxemia, hypercapnia, and subsequent increases in blood pressure and heart rate.[29,30] Snoring can lead to intermittent hypoxia, resulting in oxidative stress and inflammatory responses in the body.[31] Snoring may consequently result in endothelial dysfunction and organ dysfunction.[32] Snoring can impact lipid and protein metabolism at the genetic level, potentially leading to an elevated CVD risk.[33] However, these results have paid little attention to the difference sex.

Sex differences in the association between snoring and CVD risk were also evident in our study. Male participants demonstrated a higher risk of CVD events compared to females. This finding highlights the importance of considering gender-specific factors when assessing the relationship between snoring and CVD health. The overactivation of the sympathetic nervous system is not only crucial in the early stages of hypertension development, but is also associated with several comorbidities commonly linked to hypertension.[34] Males have higher sympathetic nervous system activity than females, which may explain the higher risk of hypertension in male patients with similar snoring conditions.[35] This is consistent with our research findings. Hormonal differences, anatomical variations, and sleep patterns may contribute to the observed gender disparities.[36] Indeed, estrogen has been found to have the ability to modulate the excitability of the sympathetic nervous system and regulate endothelial function.[37,38] Sex hormones have been suggested to influence the reabsorption of renal sodium and vascular resistance, which could potentially explain the differences in hypertension observed between men and women.[39] This might partially explain the gender difference in hypertension among patients with snoring.

Our study has identified a correlation between snoring and an elevated risk of atrial fibrillation (AF). Previous studies have also established a link between sleep apnea and an increased risk of AF.[40] The co-occurrence of snoring and sleep apnea in some of our patients suggests a potential explanation for the heightened risk observed in our study. We found that the risk of AF in male snoring patients is nearly five times that of females. Although previous studies have confirmed the association between snoring and AF,[41] there have been no studies that have examined whether this association differs by sex. Differences in atrial anatomy or tissue fibrosis may be involved in sex-specific responses to snoring in the development of AF.[42,43] Females exhibit a greater anti-inflammatory profile as a compensatory mechanism, mediated by the angiotensin type 2 receptor.[44] Postmenopausal women face an elevated risk of AF.[45] Cardiac fibrosis is crucial for the development of AF.[46] The more pronounced fibrosis in women may be associated with the upregulation of the TGFβ/Smad3 pathway and older age.[46] In our study, female patients had an average age of approximately 47 years, which may, in part, account for the gender disparities in the link between snoring and AF. Male cardiomyocytes exhibited greater late sodium current, calcium transients, and sarcoplasmic reticulum calcium content in the left atrial posterior wall than female cardiomyocytes, potentially contributing to increased ectopic activity.[47] Male mice had faster spontaneous beating rates in the pulmonary veins, greater burst firing, and longer periods of delayed afterdepolarizations compared to female mice.[48] Sympathetic stimulation can also contribute to the promotion of AF through various mechanisms.[49] This includes increasing the release of calcium ions (Ca2+), which can influence the conduction properties and refractoriness of cardiac

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tissue.[49] Additionally, sympathetic stimulation can lead to the formation of afterdepolarizations, which are abnormal electrical events in cardiac cells, and these afterdepolarizations can trigger or sustain AF.[49] Males have higher sympathetic nervous system activity than females.[35] This may potentially explain the elevated risk of AF in male patients with snoring. It has been confirmed that female snoring patients have a higher risk of CVDs compared to males in this study. Currently, there appears to be a tendency to focus more on the CVD health of male snoring patients, which includes healthcare professionals, while potentially overlooking the significance of snoring in female patients.[50] Similarly, male snoring patients have a significantly higher rate of referrals to higher-level hospitals compared to female snoring patients, enabling them to receive better treatment.[51] However, women with AF were more frequently symptomatic than men, and they experienced more severe symptoms.[52] In previous studies, women with AF exhibited notably higher rates of life-threatening adverse events, such as the development of acquired long QT syndrome when treated with class Ia or III antiarrhythmic drugs.[53,54] Compared to male patients, female atrial fibrillation patients have a higher rate of surgical complications, and the surgical outcomes are also less favorable.[55,56] Therefore, it's crucial to also pay attention to female snorers.

Our study underscores the distinct gender disparities in the connection between snoring and CVDs, notably atrial fibrillation. Nonetheless, the underlying mechanisms and clinical characteristics are intricate. Further research into gender variations in the correlation between snoring and CVDs is imperative. Additional cohort studies or interventional studies are required to investigate the potential causal association between snoring and CVDs. Nevertheless, these discoveries carry substantial implications for the implementation of clinical practices for preventing CVDs. There is a need for increased clinical awareness and focused screening for snoring and cardiovascular risk factors in male. Moreover, it is imperative to advocate for the implementation of routine screening for snoring in primary care settings, with a particular focus on male individuals who snore. Simultaneously, public health initiatives should focus on increasing awareness and providing community-based screening programs to facilitate early detection and management of CVDs in this male. Developing targeted clinical guidelines and health policies specifically for men may be more effective in reducing the cardiovascular disease risks associated with snoring.

Limitations

Limitations to the present study deserve attention. Firstly, despite adjusting for numerous potential confounders in the statistical models, the outcomes of the current study, being observational in nature, may have been influenced by unaccounted-for cardiovascular disease and snoring risk factors. Secondly, the reliance on self-reported data, particularly regarding snoring frequency and CVD risk factors, may introduce recall bias and misclassification. Finally, our findings can only demonstrate the existence of an association between snoring and CVD, rather than a causal relationship between the two. Further longitudinal studies are needed to investigate whether duration of increased snoring has cumulative effects on CVD.

Conclusion

Our study has revealed a significant correlation between snoring and CVD, with notable differences observed between sexes. Among snoring patients, males demonstrated a higher CVD risk compared to females. Male snorers have approximately five times the risk of developing AF and roughly double the risk of CAD compared to female patients. Increased clinical awareness and targeted screening for snoring in men can help reduce cardiovascular disease risks. Developing specific guidelines and policies for men may be more effective in addressing this issue.

Ethics Approval

The NHANES study received approval from the Institutional Review Board of the National Center for Health Statistics (No. Continuation of Protocol #2011-17 and Protocol #2018-01). More information can be found at https://www.cdc.gov/nchs/nhanes/irba98.htm. Due to the NHANES data being publicly available, this study is exempted by our institutional ethics committee.

Consent to Participate

All participants provided written informed consent.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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